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FINAL REPORT

on

AN ASSESSMENT OF OPPORTUNITIES IN ALBERTA RELATED TO CAD/CAM TECHNOLOGY

to

ALBERTA ECONOMIC DEVELOPMENT

December, 1983

by

BATTELLE
Columbus Laboratories

NICHOLS APPLIED MANAGEMENT

ALBERTA MICROELECTRONICS CENTRE

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SUMMARY AND CONCLUSIONS

Over 600 specific opportunities for CAD/CAM utilization were identified even though no attempt was made to be exhaustive. These specific opportunities represent 11 major opportunity areas. Utilization/application in existing industry, development of new products and process and areas for R&D in existing industry and in potential new industry are included. From a technology viewpoint, short-term applications and development opportunities are possible in three areas:

- Software development and applications based on capability of the oil industry in computer technology
- Sensors and monitoring equipment
- Application of CAD/CAM in Alberta resource related industries.

Major conclusions of the study for capitalizing on these opportunities are the following:

(1) World competition in CAD/CAM development and application of technology is high. Timely development and utilization/application of the CAD/CAM cluster of technologies is a vital element in the competitive survival and economic growth strategies of almost all industrially developed nations. In some form, each country is supporting CAD/CAM technology development in order to maintain its competitive position.

(2) With their limited resources and as yet limited utilization of CAD/CAM technology, Alberta companies need to carefully select, for emphasis, areas which can lead to market niches and which capitalize on present strengths.

(3) A market niche is identified. The focus of worldwide CAD/CAM developments to date has been on manufacturing applications; resource industry applications have been relatively neglected. Therefore, an opportunity is

present to develop a CAD/CAM niche aimed at satisfying both internal and external emerging world needs for CAD/CAM technology "products" oriented to resource industries' needs. Technology needs to satisfy Alberta's manufacturing industry can be adapted from developments by other countries.

Alberta has several significant resources which can be brought to bear on developing CAD/CAM technology utilization and hardware production. Among these are:

- An in-place educational structure which could train human resources at all required levels.
- Selected CAD/CAM related organizations, both government and industry, which could provide the basis for CAD/CAM industry growth.

However, financial and educational resources as yet have not been oriented to CAD/CAM utilization and the private sector is only beginning to emphasize utilization of "high technology" such as CAD/CAM.

In this report the information supporting the above conclusions is organized under the following headings:

- A 10-year world view of CAD/CAM technology and business
- Alberta and CAD/CAM - A comparison
- Opportunities for Alberta in CAD/CAM.

Details are presented in several appendices.

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INTRODUCTION

As part of its mission of promoting growth, competitiveness, and diversification in the Alberta economy, Alberta Economic Development (AED) is exploring ways to encourage the use of new technologies. One of the new and emerging technologies which is attractive for encouragement is the cluster of technologies referred to as CAD/CAM (computer-aided design and computer-aided manufacturing). This technology cluster emcompasses a variety of identifiable separate technologies; however, all are related to computer control or some sort of automation. At the outset, the CAD/CAM technology cluster is potentially attractive from three distinct viewpoints:

- CAD/CAM is useful to current and future Alberta industries as a versatile tool to improve productivity and thus enhance Alberta industries' ability to compete worldwide.

- CAD/CAM allows entry into high technology markets through the development, manufacture, and sale of a set of products (components, software, peripherals, and/or major systems).
- CAD/CAM will facilitate building a research and development (R&D) capability which could be useful to many indigenous industries.

An objective of this study was to explore the potential for using, developing, and manufacturing equipment and software in Alberta.

This study was exploratory in nature so its initial scope was broad, i.e., all of the related major and supporting CAD/CAM technologies were briefly reviewed with no a priori judgments as to what scale system may ultimately be practical to use or produce.

Major worldwide emphasis in CAD/CAM is on the manufacturing industries. In Alberta, the manufacturing sector is a relatively small part of the GDP. Thus, analysis and applications of CAD/CAM to other economic sectors in Alberta was important. Some of these sectors are oil and gas, mining, agriculture, cattle raising and meat packing, lumber and wood products, and construction related to emphasis on the resource industries. Analogies to and implications of CAD/CAM in the present industries for productivity improvement and for searching out potential market niches for Alberta were sought.

The CAD/CAM technology area involves a cluster of technologies ranging from various technical design and manufacturing techniques for relatively unsophisticated, small products to overall integrated manufacturing schemes for large-scale production or manufacture of sophisticated systems.

The definitions of segments of CAD/CAM used in this study are the following:

(1) Computer-Aided Design (CAD) which includes: products, processes and systems designed to capture engineering data, the analytical software developed for manipulating data, and computer-aided process planning and parts programming for numerically controlled (NC) equipment and machine tools.

(2) Group Technology (GT) which includes: the design of product and process classification and coding systems and the alignment of manufacturing processes to produce product families.

(3) Manufacturing Planning and Control Systems (MP&CS) which includes: manufacturing resource planning, distribution resource planning, simulation and optimization techniques and software, shop floor data collection systems and management graphics and support systems.

(4) Automated Materials Handling (AMH) which includes: automated storage and retrieval systems, automated guided vehicle systems, materials and parts storage and transport systems, and miniloaders.

(5) Computer-Aided Manufacturing (CAM) which includes: automated assembly; computer-aided inspection, testing and process controls; conventional and numerically controlled machine tools and flexible manufacturing systems and automated packaging.

(6) Robotics which includes: programming languages, sensors, end effectors and equipment (part of flexible manufacturing systems).

(7) Computing Technology which includes: the hardware, software, data base, and telecommunications technologies that constitute the development and enhancement of products in this field.

These CAD/CAM technologies are closely interrelated to other technologies such as microelectronics, computer hardware and software development, and machinery design. Assessment of these latter technologies are not part of this study.

Many CAD/CAM technologies are in their infancy and in some applications, such as primary production of raw resources, are at the prenatal level. Nonetheless, given the nature of the Alberta economy, these applications could potentially be the most important. Consequently, the CAD/CAM technologies were looked at with a 10-year time frame in mind. A 10-year state-of-the-art technology forecast can be made with reasonable assurance. Technology forecasting is an assessment of the state of the art at some future date in applying scientific developments.

A worldwide perspective was required for a number of reasons. Among these are:

- Each CAD/CAM technology is being advanced at various locations throughout the world
- To identify potential niches, foreign competition must be evaluated
- Sources of technology available to domestic firms should be identified
- To speed Alberta's application of CAD/CAM technology, potential worldwide markets for products must be evaluated to estimate export potential
- Other business and technical factors shaping progress of technology must be identified in order that Alberta companies understand their competition.

Attention was paid to Japan and West Germany, in addition to the U.S., since these countries are world leaders in technology development. Other Western European countries are making progress at present, but more slowly than the three highly industrialized countries mentioned.

In this report, information is presented in the following sequence:

- A 10-year world view of CAD/CAM technology and business
- Alberta and CAD/CAM - a comparison
- Opportunities in Alberta for CAD/CAM products, utilization and application, and research and development.

Each section summarizes the subject while the details are contained in the appendices.

A 10-YEAR WORLD VIEW OF CAD/CAM TECHNOLOGY AND BUSINESS

Major emphasis of CAD/CAM development programs is aimed at the manufacturing industries. Special emphasis is being given to discrete parts production. The continuous process industries have long used computer aids in production monitoring and are a less important development objective for CAD/CAM worldwide. Lesser emphasis is being given to non-manufacturing industries. This discussion summarizes CAD/CAM technology developments which directly relate to Alberta. For a more detailed description of CAD/CAM technology development and business trends, see Appendix A.

CAD/CAM State of the Art - Manufacturing Industries

CAD/CAM technologies are composed of hardware and software components. Hardware for CAD/CAM, including CNC machine tools, automated material handling, robotics, and computing hardware, is highly developed. Most of the hardware developments are advancing through slow evolution, but computing hardware is advancing rapidly. One weak link in CAD/CAM hardware is sensor technology, which must develop more rugged and accurate sensors. Selected sensor developments are a possible opportunity for Alberta.

CAD/CAM software is less advanced than the hardware. Certain application packages, such as Turnkey CAD/CAM, Finite Element Modeling, and MRP are highly developed. Other applications packages, such as Off-Line Robot Programming, Computer-Aided Process Planning, and Manufacturing Systems Simulation, are just emerging. The major problem for software developers is integrating the various specific application packages into a cohesive package. The major obstacles to integration are the information gaps among the applications software packages. Alberta has skills which could be applied to software integration.

Major development programs are underway in the U.S., Japan, and Western Europe to improve CAD/CAM technologies. U.S. programs mainly involve the aerospace industry and are directed toward implementing existing technology and improving software. Japanese programs are mainly directed toward implementing existing technology and improving hardware. Programs in Western Europe are generally attempting to standardize and modularize existing technology.

CAD/CAM Technology Forecast - Manufacturing Industries

CAD/CAM technology will be increasingly developed, enhanced, and applied in all major industrial countries over the next 10 years. This assertion is based on the following evidence:

- Computing technology is already sufficiently developed to handle virtually all foreseeable requirements of any CAD/CAM technology. Additionally, the cost/capability ratio of computing technology is decreasing exponentially over time.
- Skilled labor shortages are being experienced by all industrial countries. Skilled labor availability in manufacturing industries could continue to decrease, while the cost of all skill levels of manufacturing labor should continue to rise.
- The rising cost of capital based on high interest rates is driving manufacturing firms to seek lower inventories and higher equipment utilization.
- Increasing worldwide industrial competition will drive firms to higher productivity and improve quality.

The goal of most major CAD/CAM technology programs would be a computer-controlled automated factory coordinated with management functions. While automated mines, drilling rigs, etc., are possible, such applications are receiving minimal attention. However, there are several barriers to fully automating an entire factory. Some of these barriers are:

- Investment - large amounts of capital are required.
- Data Base - a data base structure which provides sufficient information for design, manufacturing, assembly and testing (and management, marketing, finance, etc.) has yet to be developed.

- Operating system - an operating system must be developed to manage the huge volumes of data which would have to be processed for real-time control of a manufacturing facility.
- Sensors - improved vision and tactile sensors will be required for most automated flexible assembly operations. Flexible assembly applications are rare at the present time.
- Diagnostic and automated repair in process - complete removal of maintenance personnel from the shop floor will be unlikely in the next 10 years. Automated machine tool diagnostics are relatively undeveloped and study of fundamentals is required. Automated tool repair is non-existent. Both diagnostics and repair require highly developed sensors.
- Mechanical capability - the mechanical capability of robots must be improved. Robots need mobility and increased speed, accuracy, and dexterity particularly in assembly operations.

It is likely that the barriers to data base and operating systems will be solved in the U.S. within the next 5 to 10 years. The most significant progress in sensors, robot mechanical capability, and automated diagnostics and repair will more likely occur in Japan. Both Japan and the U.S. will undoubtedly have showcase factory-wide integrated CAD/CAM installations by 1988.

The desire to reduce investment cost to industry is resulting in a trend toward standardization, modularization, and flexibility to reduce custom engineering in both government programs for defense oriented plants and private vendors. Standardization allows the integration of software and hardware from several sources into a single system. Modularization allows low-cost design of CAD/CAM systems tailored to the user's requirements by combining "building blocks" of automation. Flexibility ensures that the CAD/CAM system will continue to meet the user's requirements as product requirements changeover time. The same equipment needs only minor update (software and hardware) to continue to be useful.

Detailed forecasts for each CAD/CAM technology area for the years 1988 and 1993, as well as the historical development of these technologies, is contained in Appendix A.

CAD/CAM Technology Forecast - Nonmanufacturing Industries

The advances in CAD/CAM technology developed for the manufacturing industries will have many applications in other industries. Computing technology will be applied to nonmanufacturing industries over the next 10 years in the following areas:

- Processing of remote sensing data for agriculture prediction and evaluation, and for exploration for oil and minerals.
- Project planning facilities design for large oil, mining and forestry projects using applications software and graphics.
- Data base management and applications software for day-to-day management of farms, mines, oil fields, and logging operations.
- Work rate controllers for large pieces of equipment, such as mining machines, bulldozers, trucks, and tractors.
- Use of real-time sensed data and computer processing for control of oil-well drilling and farm tractors.

For more details, see Appendix A.

Widespread implementation of automatically guided and/or robotic control of large, mobile pieces of equipment is not foreseen in any of these industries in the next 10 years. However, special-purpose robots could find applications in specific hazardous environments.

CAD/CAM Business Forecast

Business forecasts for CAD/CAM related products show relatively high growth rates compared to world economic forecasts. This report uses those optimistic forecasts because of international pressures to improve productivity and because initial (1983) market values are small. Thus, large growth rates are possible over short periods of time.

The CAD/CAM business forecasts in several areas, which are the following:

- Flexible Manufacturing Systems (FMS) - The total world market for Flexible Manufacturing Systems in 1982 was $4 billion. Utilization of such systems is expected to grow at about 25 percent per year to a total of $37 billion in 1992. Japan is the leading consumer of FMS, followed by Western Europe and then the U.S.
- CAD/CAM Equipment - This section discusses only equipment which meets a strict definition of CAD/CAM, not the more extended view of this study. Sales of CAD/CAM equipment are dominated by U.S. vendors. Of the various types of vendors, turnkey systems manufacturers controlled in excess of 75 percent of the 1982 market. Battelle estimates that the total sales for CAD/CAM will grow about 25 percent annually through 1987 and at a faster annual rate through 1992. The U.S. is the leading consumer of CAD/CAM equipment, followed by Japan and then Western Europe. The mechanical industry is the leading consumer of CAD/CAM equipment, followed by electronics, AEC (architectural, engineering, and construction), and finally mapping.

- Robotics - The total worldwide market for robots was $660 million in 1982 and is expected to grow at a rate of about 20 percent per year over the next 10 years to $4.6 billion in 1992. The leading consumer of robotics is Japan, followed by the U.S. and then Western Europe. Application of robotics to assembly is anticipated to experience rapid growth in the 1987-1992 time frame.
- Automated Materials Handling Equipment - The worldwide market for automated materials handling equipment was $1 billion in 1982. This market is expected to grow at a rate of about 20 percent per year over the next 5 years to $2.5 billion in 1987 and higher annual rate from 1987 to 1992 to $10.5 billion.
- Software - Manufacturing management software, a $150 million worldwide market in 1982, is expected to grow at about 25 percent annually through 1987 (to $500 million) and at much higher annual rates from 1987 to 1992 (to $3.3 billion). The worldwide CAD/CAM software market is expected to grow 40 percent annually over the next 10 years, from $140 million in 1982 to $4.5 billion in 1992. Applications areas where high growth rates are expected to include Solids Modeling, Finite Element Analysis, Group Technology, Process Planning, and Test and Inspection Systems.

A summary of major CAD/CAM related markets for 1982, 1987, and 1992 is given in Table 1.

Funding for CAD/CAM Developments

In most areas of the world, advanced development of CAD/CAM is supported by government projects in one form or another. The support of development of CAD/CAM by government varies by geographic area. The U.S. and Japan are leading generally with Western Europe tending to specialize as shown in Table 2. There is a tendency for Japan to Emphasize hardware more than does the U.S.

TABLE 1. ESTIMATED WORLD MARKET FOR SELECTED CAD/CAM RELATED PRODUCTS

	Estimated World Market $U.S., millions		
Product Class	1983	1987	1992
Flexible Manufacturing Systems	4,000	12,000	30,000
CAD/CAM Equipment	1,300	3,700	15,000
Robots	700	1,800	4,600
Automated Material Handling	1,000	2,500	10,500
Software Manufacturing and CAD/CAM	300	1,300	7,800

Source: Battelle.

TABLE 2. WORLD COMPETITION IN TECHNOLOGY DEVELOPMENT

Technology	Geographic Competition		
	U.S.	Japan	Western Europe
CAD	X	0	0
CAPP	X	0	0
Group Technology	X	0	X
Material Resource Planning	X	X	0
Automated Materials Handling	X	X	0
NC, DNC, CNC	X	X	X
FMS	X	X	0
Robotics	0	X	0
CIMS	X	0	0

Source: Battelle.

X - Leader

0 - Minor

United States

In the U.S. alone, roughly $83 million was spent by the U.S. Air Force on manufacturing technology aimed at automated manufacturing systems. Other defense services and private industry are allocating similar if not larger funding to CAD/CAM related R&D.

Much of this funding has a long-term goal of an operating plant. In reaching the goal any research and development required is funded. In addition, the National Bureau of Standards is developing standard duty formats for CAD and CAM data transfer.

Other private and nonprofit organizations are also developing CAD/CAM technology. Some of these programs are government funded.

Japan

In Japan, the major development program is the National Project coordinated by the Research Association for Flexible Machining System (FMS) Complex. At least five companies are cooperating with the government. The FMS complex is an experimental plant to be commissioned in 1984. It will be a factory-wide integrated FMS.

University level research is aimed at several technology areas which are barriers to fully unmanned automation. Included are integrated CAD/CAM hardware, machine tool diagnostics, mobile repair robots, and flexible assembly. Other very advanced programs are being pursued.

Western Europe

Development programs in Western Europe in CAD/CAM and FMS technology are aimed at standardization, modernization, and promotion of industrial use. Programs are funded at several special centers and at the universities.

Technology Utilization

Several trends are apparent which bear on the future use of CAD/CAM. Among these are:

- Paperless operations - the goal of most of the CAD/CAM systems is to replace hard copy with computers.
- More flexible manufacturing systems - flexibility in the system will allow product changes without major equipment modifications. Changes in software only are required.
- Evolutionary growth - much of the technology needed for the next decade is available. No breakthroughs are needed for application.
- Change from hardware linked to computer-controlled systems machines will become more versatile through computer control.
- Modular tools - tools and tool changers and machines will be assembled into cells of several types for flexibility
- Technology (user friendly) software orientation will allow inputs to the computer to be in the user's language rather than computer language.
- Adaptive controls will tend to compensate for changes in conditions automatically. Examples are tool wear, temperature, etc.
- Real-time control and simulation will be utilized on-line toward the end of the decade.

It is forecast also that many developments will not be significant (25 percent of potential users having installation in place until around 1990). Even later applications could result from a world depression. One study showing several events and dates of realizing events is given in Table 3.

Larger companies are expected to install CAD/CAM related technology more rapidly than medium and small. Results of one study are shown in Table 4.

TABLE 3. FUTURE APPLICATIONS OF CAD/CAM

Event	Year		
	U.S.	Japan	Western Europe
25% CAD Used to Make Machine Parts	1985	1990	1990
20% of Industry Uses MRP and CAPP	1990	1986	1990
50% of Paperwork Computerized	1987	1988	1988
25% Factories (<1000 People) Implemented CAD	1990	1995	1995
25% of Shop and Floor Graphics on CRT	1990	1995	1990
10% of Machining Operations Uses Group Technology (<1000 Employees)	1990	1990	1993
More Than Showcase Computer Integrated Factories	1995	1995	1998

Source: Production Engineering

TABLE 4. APPLICATION OF AUTOMATION

Type Automation		% of Companies No. of Employees 1-100	 100-500	 500+
CAD/CAM	Now	2	8	50
	5-10 Years	15	35	90
CNC/FMS	Now	0	4	65
	5-10 Years	10	25	96
Industrial Robots	Now	5	12	45
	5-10 Years	20	35	83

Source: National Research Council, Committee on Computer Aided Manufacturing, 1981.

ALBERTA AND CAD/CAM - A COMPARISON

The implications to Alberta of worldwide developments is that most of the technology needed by Alberta firms has been developed. What is needed is adaptation of that technology in solving Alberta's problems. Some of this adaptation will require development of products and processes suited to Alberta.

CAD/CAM in Alberta

To determine the uses, needs, and support required for CAD/CAM, senior Alberta industry executives in over 40 companies were interviewed. This information was used to determine the present and planned activities in Alberta directed toward CAD/CAM technology. Some conclusions from the interviews are summarized below. For a more complete analysis, see Appendix B.

The technologies of CAD/CAM are quite new to Alberta's industry (within the last 4 years) and robotic equipment is only being introduced this year. These tools are the result of a basic push to cut costs, improve quality and increase productivity.

Part of the reason international competition is so strong today in a recessionary market is that other countries are now applying the new microelectronic technologies more effectively. There are many natural strengths in Alberta on which to recover and grow with spin-offs from success and diversification. But, new tools are needed in most production, manufacturing and processing operations. New high technology is available now but it takes a fair amount of initiative, incentive and assistance to implement new ideas when funds are thin and short-term demand is down.

Alberta has about 60 CAD systems in operation. They are applied mostly to the mapping, architectural and engineering fields. Alberta has about 10 percent of Canada's systems; Canada has about 600. Applications in Alberta are in the large engineering, construction and exploration industries.

It is apparent from the interviews that the push for technology improvement in industry is from middle management and not from senior management where it is needed. This requires an educational and awareness thrust within industry.

At present, very few companies have any long-term objectives or strategies for applying the CAD/CAM technologies. They are only generally aware of the benefits of CAD/CAM. Many companies lack ideas for present and future applications. Further, there is a shortage of consultants in the province for enhancing more awareness.

Few companies in Alberta are developing CAD/CAM products. Their applications are mapping and CAE (Computer-Aided Engineering) for civil engineers.

It is important to note that the larger companies using up-to-date technology now are doing fairly well compared to their competitors. Specific examples are engineering firms using CAD and manufacturing firms using CNC equipment.

Analysis of the ideas and opportunities obtained from industry indicates that CAD/CAM technology would have the most applications in the following fields:

(1) Mapping
(2) Architectural and construction (complete building and plant data bases)
(3) Image processing and geophysical processing (high resolution - three dimensional)
(4) Resource management using interactive graphics
(5) Process control
(6) CAM using direct numerical control
(7) Software development.

In conclusion, there is a need for a CAD/CAM thrust in the province. It can now be applied to almost all industry sectors and disciplines. It is one of the best productivity tools to date available to industry. Introduction and support of CAD/CAM is required for many companies to survive competition in international markets, while developing existing strengths in Alberta.

A Comparison of Alberta and Worldwide CAD/CAM Technology

Major Alberta industries are not in the mainstream of worldwide emphasis for CAD/CAM technology development. In one sense this mismatch is a constraint to utilization of CAD/CAM technology. However, this mismatch presents opportunities for Alberta industry. Table 5 shows the major constraints and the opportunities associated with each constraint.

Mismatch of Alberta Economy and Mainstream CAD/CAM Emphasis

World major CAD/CAM technology development is aimed at the manufacturing industries. The manufacturing contribution to GDP in Alberta is small(1), roughly 9 percent in 1981. Even within the manufacturing sector, food and beverage, petroleum and coal, and chemistry and chemical production subsectors are about half of the contribution of manufacturing to Alberta GDP.

Alberta has a resource based economy. Mining, which includes oil and gas, was almost 21 percent GDP in 1981. Construction, transportation, finances and services which are associated to mining total almost another 41 percent of the Alberta GDP.(1)

The lack of emphasis of worldwide CAD/CAM technology thrusts allows a market niche for Alberta industry. CAD/CAM technology has many applications in resource related industries. Because these industries are being neglected, Alberta companies can adapt available CAD/CAM technology to the resource industries to improve productivity. A potential export market exists because products developed for Alberta could be utilized by resource industries outside of Alberta.

Small Alberta Population and Markets

Major companies selling and developing CAD/CAM products tend to neglect specific application to Alberta because of the small markets. An opportunity exists for adapting CAD/CAM technology to small scale markets.

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(1) Alberta Statistical Review, Foster Report, September 1980, Chapter 3, Vol. 2.

TABLE 5. CONSTRAINTS, BARRIERS, AND OPPORTUNITIES FOR CAD/CAM TECHNOLOGIES IN ALBERTA

Constraints	Opportunities
Mainstream CAD/CAM efforts are oriented to other than Alberta strengths	Opportunities for directing CAD/CAM to resource and other sectors ignored elsewhere
Small population base, labor force and domestic markets	Opportunities for small-scale market and industry products/applications
Lack of large companies with major resources	Opportunities for orienting development to small users, non-conventional areas
Lack of well developed support industry structure	Opportunities to initiate assembly operations
Canadian federal government emphasizing industrial growth in central provinces	Opportunities for non-manufacturing resource-based applications

These small markets could be stepping stones to larger markets outside Alberta.

Predominance of Small Companies

CAD/CAM is equally useful to small companies as well as large. Developments directed to applications in small companies are just starting. The many small companies in Alberta represent a significant market for products and processes tailored to small companies.

Lack of Well Developed Industry Structure

The world CAD/CAM industry has many segments (see Figure 1). These are broadly divided into software and hardware. Hardware divides into electronics and mechanics subsegments. In support of this CAD/CAM industry are other industry sectors such as basic metals, metal fabrication, electronic components, etc.

The software industry subsector is interesting to Alberta because generally it is much less capital intensive than the hardware subsector. Alberta already is providing some specific application software. The major resources requiring further development are human resources and installed computer facilities. Both are available.

The hardware subsector is more complex. Mechanical equipment production is quite capital intensive. Little is being done in Alberta.

Production of electronics equipment holds promise. Alberta companies could start with assembly and integrate backward into component production. Several Alberta companies are assembling electronics. Alberta engineering consulting firms are also providing services.

Mission Oriented R&D

R&D for CAD/CAM related technology is multifaceted and requires a multidisciplinary team approach. Alberta has experience with multidisciplinary R&D in the AOSTRA program. Some of this experience could be transferred to CAD/CAM technologies.

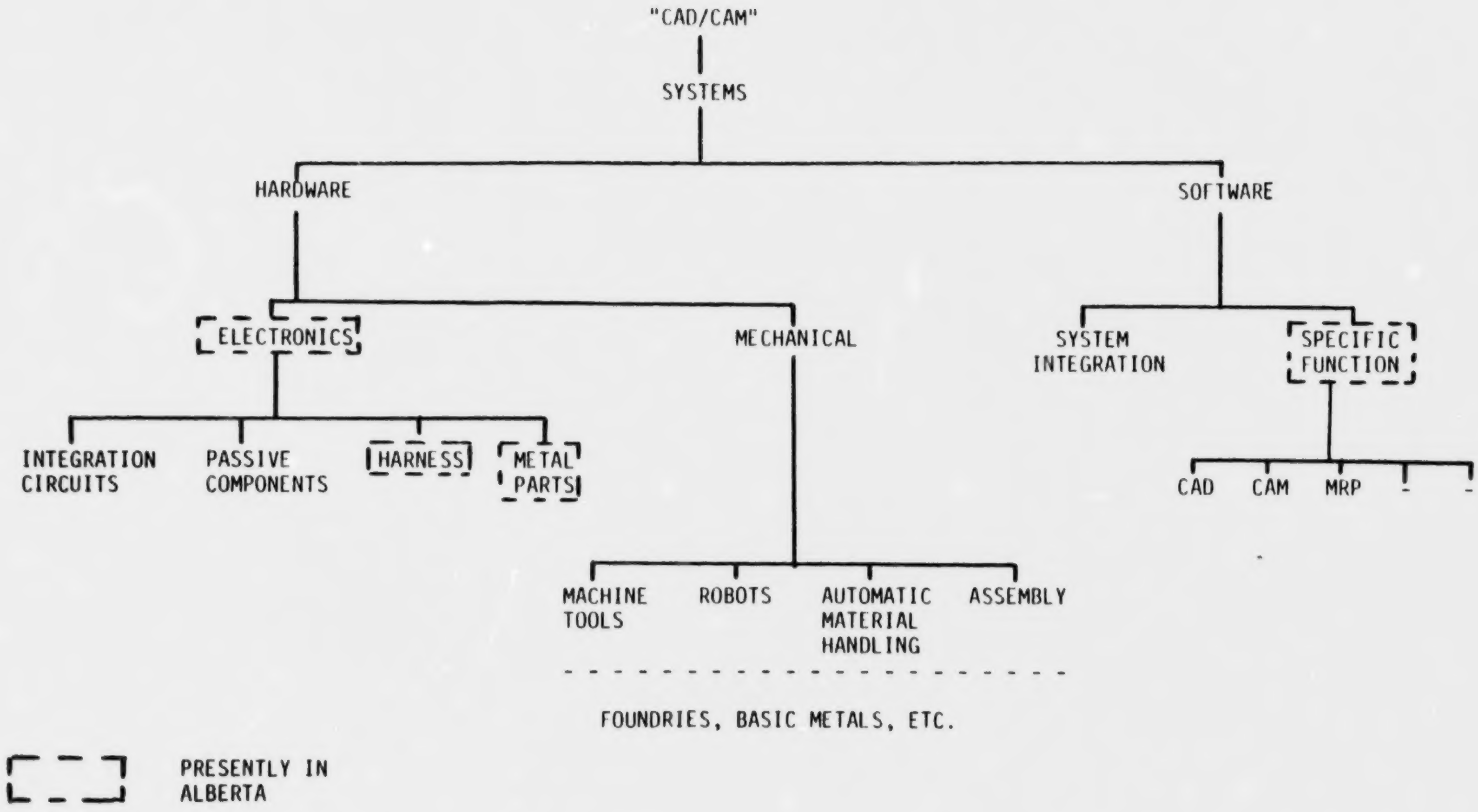
"CAD/CAM"
SYSTEMS
HARDWARE
SOFTWARE
ELECTRONICS
MECHANICAL
SYSTEM INTEGRATION
SPECIFIC FUNCTION
INTEGRATION CIRCUITS
PASSIVE COMPONENTS
HARNESS
METAL PARTS
MACHINE TOOLS
ROBOTS
AUTOMATIC MATERIAL HANDLING
ASSEMBLY
CAD
CAM
MRP
-
-
FOUNDRIES, BASIC METALS, ETC.
PRESENTLY IN ALBERTA

FIGURE 1. CAD/CAM INDUSTRY STRUCTURE FROM SUPPLIER VIEWPOINT

Canadian Government Emphasis on Industrial Development of the Central Provinces

The lack of emphasis by the Canadian government on technology application to the resource industries presents an opportunity similar to the lack of emphasis of world CAD/CAM effort. Alberta can pioneer application of CAD/CAM technologies to resource industries and build a market niche with this technology.

OPPORTUNITIES IN ALBERTA FOR CAD/CAM PRODUCTS, UTILIZATION AND APPLICATION, AND R&D

Four activities were key to selecting opportunities in CAD/CAM for Alberta. These are:

- Generation of a list of potential opportunities
- Defining the criteria for selection
- Utilizing a cost effective selection process
- Defining the importance of opportunity for Alberta.

Philosophical guidelines used in this study which guided the activities are the following:

- The goal of opportunity identification is to identify some good opportunities
- It is not an objective to identify the best opportunity or to strictly priorize the list. Categories of good, average, or poor potential are all that is expected at this point. Later, detailed study will provide the detailed information needed for final decisions.
- Failure to identify a few good opportunities should not cause major concern. It is not possible to cost effectively identify all good opportunities.
- The goal of this study was to determine if some good opportunities exist.

Opportunity Identification

In excess of 600 individual opportunities were identified in this study. This complete list is contained in Appendix E. The total list of identified opportunities is presented without the judgemental bias of the study group since some of the suggestions eliminated by the study group may trigger suggestions for other potential opportunities to the readers.

Information utilized in identification of opportunities for Alberta came from a variety of sources. Included are:

- Interviews with key industry, education and government officials in Alberta
- Meetings with Alberta industry representatives and within Battelle
- CAD/CAM applications in manufacturing described in literature
- Review of industry/product structures
- Review of analogies of CAD/CAM to industries other than manufacturing
- Other information available to team members.

Definition of Selection Criteria

Criteria for screening opportunities were developed from key information received during interviews with Alberta leaders, literature on Alberta goals, objectives, and constraints, a 10-year world view of CAD/CAM, and an analysis of present CAD/CAM usage in Alberta. Criteria are of two types as follows:

(a) Elimination and
(b) Ranking.

Both types of criteria were derived for each of three kinds of opportunities for CAD/CAM technologies in Alberta. These three kinds of opportunities are:

- Application/utilization
- Manufacture of products or provision of service
- Research and development.

The two types of criteria for each of the three kinds of opportunities are given in Appendix D, along with a brief discussion of sequence of steps in using the criteria.

Elimination Criteria

Elimination criteria are also called culling, or go/no-go. The objective is to determine a few essential criteria which have to be met individually in order for an opportunity to survive. The criteria are stated such that a "yes" answer eliminates the opportunity.

Ranking Criteria

Ranking criteria are used to priorize opportunities. Each criterion is rated on a 1 to 5 scale, with 5 being the desired position. After proper weighting, a score is derived which is used to priorize the opportunities.

Selection

Efficient screening and selection methods are essential for reducing, at a reasonable cost, a large number of ideas generated to a more manageable number. A sequential screening process has been found by Battelle to be highly successful in pinpointing good ideas in an extensive list of possibilities. The objective of the screening process is to reduce the list of possibly hundreds of ideas to a dozen or so of the more attractive ones. The process will not necessarily uncover the best idea. The sequential screening process is based on a series of steps whereby easy to use criteria (elimination criteria) are used first proceeding through more difficult to apply criteria (scoring criteria), as a list of ideas is progressively reduced. No attempt is made to conduct an in-depth investigation of each idea during the sequential screening process. Rather, the screening process capitalizes upon the sum total of individual participant's knowledge, experience, biases, and upon readily available information.

In this study the screening process consisted of two formal steps using the criteria defined and discussed earlier. Once the formal screening was completed, the project team met and rationalized the results.

Types of Opportunities

The opportunities which emerged from scoring in many cases represented a detail on one hand or a large aggregate on the other. All variations in between were found. Two methods were used to analyze the individual opportunities. In one method, eleven areas of application were derived by grouping similar opportunities and then aggregating these upward to broader subjects which could be considered at a strategic level.

These eleven application areas are:

- Control and monitoring
- Resource management
- Operational management
- Education software
- Data bases
- Automated manufacturing plants
- Planning and project management
- Hazardous and unpleasant environments
- Energy management
- Special real-time signal processing
- Material usage optimization.

From another viewpoint, the opportunities can be classifed by type of technology opportunity. Three major classifications result as follows:

- Software - which includes all application areas except those noted below.
- Sensors and control - included in control and monitoring
- CAD/CAM - technologies defined in the terms of reference, except software.

Opportunity areas and technology areas are discussed separately.

General Application Areas

The eleven general application areas could impact Alberta from a number of viewpoints. Included are

- Industry sectors impacted
- R&D possibilities
- Application/utilization of CAD/CAM
- Possible CAD/CAM related products
- Technologies addressed.

The eleven application areas were priorized into two categories: best opportunities and good opportunities. All eleven were considered appropriate for Alberta.

Application Area

- Best
  - Control and Monitoring
  - Resource Management
  - Operational Management
  - Educational Software
  - Data Bases
  - Automated Manufacturing Plants
- Good
  - Planning and Project Management
  - Hazardous and Unpleasant Environment
  - Energy Management
  - Special Real-Time Analysis
  - Materials Usage Optimization

These eleven application areas have varying degrees of potential impact and the impact will be felt in different time periods as shown in Table 6.

Opportunities in R&D, application, utilization, and products in CAD/CAM are represented to a varying degree in the eleven application areas. Table 7 indicates which industries in each of the three types of application areas could benefit.

The implication of each of the eleven application areas to Alberta is discussed under the following headings:

- Definition of Opportunity
- Application to Alberta
- Benefits to Alberta
- State of Art.

Control and Monitoring

Definition. Control and monitoring refers to the use of sensors for control of equipment or simply to monitor some parameter in a piece of equipment, in the environment, in an animal, or in a human being. Control and monitoring is the first step in automation. In control applications, predetermined control logic operates the equipment based on a set of instruc-

TABLE 6. TIMING AND DEGREE OF IMPACT OF OPPORTUNITY

Opportunity Area	Dimensions (Major Emphasis)	
	Timing*	Impact
Control and Monitoring	M,L	High
Resource Management	Continuing	High
Operational Management	Continuing	High
Education Software	S,M	High
Data Bases	S	High
Automated Plants	L	High
Planning and Project Management	S	Moderate
Hazardous and Unpleasant Environments	M,L	Moderate
Energy Management	Continuous	Moderate
Special Real Time Signal Processing	S,M	Moderate
Material Usage Optimization	S	Moderate

* S = short (2-5 years)
M = medium (3-10 years)
L = long (8-20 years)

TABLE 7. SUMMARY OF CONTENT OF APPLICATION AREAS

Opportunity	Industry	Product	Applications	R&D
Optimization	Metal Fab		X	X
	Forestry Products		X	X
	Glass		X	X
	Meat		X	X
Energy Management	Mining		X	
	Factories (Manufacturing)		X	
	Buildings (A&E)	X		
	Process Industries		X	
Resource Management	Forest Products	X	X	X
	Mining	X	X	X
	Natural Resources	X	X	X
Control and Monitoring	Agriculture	X	X	X
	Oil	X	X	X
	Irrigation (Agriculture)	X	X	X
	Sensors & Systems (Manufacture)	X	X	X
	Medical	X		X
Automated Manufacturing Plants	Manufacturing		X	X
Operational Management	Factory (Manufacturing-discrete parts)		X	X
	Farm (Agriculture)		X	
	Plants (Process)	X	X	
	Productivity Software	X	X	X
Special Real-Time Signal Processing	Oil (Seismic)		X	X
	Remote Sensing		X	
	Service Community and Regional Development		X	
Data Bases	Construction		X	X
	Farming		X	
Education Software	Service	X	X	
Planning and Project Management	A&E	X	X	X
	Construction	X	X	X
	Community Planning		X	X
Hazardous and Unpleasant Environments	Manufacturing	X	X	X
	Mining	X	X	X
	Oil	X	X	X
	Forest Products	X	X	X

tions and on the feedback signal from the sensors. In monitoring applications, sensed data (perhaps after some analysis) are communicated to a human operator or manager, who makes a decision based on the data. There are many opportunities for the development and application of sensors and control algorithms, particularly in agriculture, medicine, and manufacturing.

Application to Alberta. Improving productivity in a variety of industries through use of CAD/CAM concepts requires sensors and monitoring systems. In order to keep Alberta industry competitive (domestically and foreign) higher productivity is required. In many industries now (e.g., agriculture) decisions are based on opinion. In good times there is a chronic labor shortage in agriculture; automated systems are needed. Also, Alberta has a good base in medical research but has not capitalized in application of results to equipment which could be marketed worldwide. A team of medical doctors and technologists is needed to develop equipment. Both are available in Alberta.

Alberta has about 100 manufacturing companies; three-fourths of these are oriented to resources and one-half to control and monitoring. These provide a good base for industry growth. Opportunities are available in Far North applications and remote telemetry.

Downstream Benefits. Downstream benefits of control and monitoring include:

- More efficient agriculture production
- Less labor and less energy required in agriculture production
- More correct diagnoses in medicine
- New export products in agriculture and medicine.

State of the Art. Developments of control and monitoring in agriculture are negligible. Possibilities include equipment energy management, implement control, and livestock monitoring. In medicine, certain analyses such as ECGs have been directly linked to small computers which analyze and diagnose from the sensed data. Possible concepts include feedback control of anesthesia or life support systems.

Resource Management

Definition. Resource management systems combine software and data bases to aid in planning and managing the exploitation/conservation of natural resources, such as lumber, oil, coal, water, and minerals. Data bases can be constructed from remote or on-site sensing data and can contain current and historical data. Software algorithms manipulate the data to simulate the effect of management alternatives. Data and simulation results are frequently presented through a graphics post-processor in the form of graphs, plots, or visual simulation of site topography.

Application to Alberta. Alberta is a resource dependent province and needs to manage those resources to optimize return to the province. Expertise exists in the form of resource data banks much of which belong to private industry. As the world economy recovers, more resource development will occur in the next decade. In the absence of hard information for long-term planning of resource management, short-term opportunistic decisions (sometimes politically motivated) will rule. Long-term analysis and plans perhaps using simulation to test impact of alternatives would be very useful. Scenarios developed around selected alternatives could be constructed. At least one institutional data base exists in ERCB as a start.

Downstream Benefits. Downstream benefits of resource management systems include:

- More efficient operations in mining, oil, forestry, etc.
- Utilization of resources more aligned to overall Albertan goals (if centralized system is developed)
- Export software and services, particularly to less developed countries
- Better ability to meet Albertan and export needs for natural resources
- Improved conservation of resources.

State of the Art. Commercial systems are available for resource management, particularly for stripmining and oil. The simulation and optimization algorithms used in these systems are still relatively crude, and a good deal of judgement is required to interpret the results.

Operational Management

Definition. Operational management systems provide data and analyses to support management. Principles of operational management are applicable to virtually any type of on-going business activity. Data which can be provided include historical data bases, day-to-day operations data, and market data from time-sharing networks. Most analyses simulate the outcome of management decisions upon the operations; however, some analyses attempt to find optimal solutions to management problems. Output of data and results of analyses can be textual or graphical or both.

Application to Alberta. Alberta imports many finished goods but tends to produce custom articles. Many plants are small and cannot take time for sophisticated management techniques. In addition, transportation costs for some goods are high. Also, productivity improvement is needed. An initial answer is the upgrading of management talent for all sizes and types of companies. The specifics of the training needs to be tailored to Alberta.

Downstream Benefits. Downstream benefits of operational management systems include:

- Improved productivity for many Albertan businesses, especially small- and medium-sized firms.
- More informed decision making
- Reduced inventory and reduced dead stock
- Improved cost competitiveness of Albertan products.

State of the Art. Operational management systems are commercially available for most industries, including manufacturing, agriculture, mining, and oil. However, these commercial packages are generic in nature and almost always must be modified to meet the requirements of a specific situation. These software packages developed for Alberta may have an export market. Most analysis software is based on a network flow model of the generic operation. Of course, time-share data bases for market information are available for most industries.

Educational Software

Definition. Computer-aided instruction (CAI) operates through interactive instruction of the student at a computer terminal. Software for CAI is "user-friendly", so the student is not required to understand computers or programming. CAI software provides textual information, asks the student to reply to questions, and corrects the student for incorrect answers. CAI can be used to augment classroom instruction or for in-home or at-work instruction. The software can be tailored to the needs of the user; businessman, farmer, housewife, etc.

A significant development in CAI software has been the introduction of a "user-friendly" CAI programming language by WICAT systems. This language allows programming of courseware by a non-programmer in a significantly reduced amount of time (compared to general programming languages). Concerning possible future developments, if erasable videodisks are developed, they would be a major boon to CAI by reducing the cost of video instruction.

The following is a list of systems.

1. WICAT Systems
   Basics Division
   931 E. 300 N.
   Provo, Utah 84601

   - WICAT (offers user-friendly langauge for programming courseware)

2. Control Data Publishing
   P.O. Box 261127
   San Diego, California 92126

   - PLATO (courseware)
   - SAM (track usage on large systems)

3. McGraw-Hill International Training Systems
   1221 Avenue of the Americas
   New York, New York 10020

   - EDUTRONICS

4. McAuto
   Box 516
   St. Louis, Missouri 63166

   - Technical Training Education

There are many others.

Application to Alberta. Alberta is strong in providing educational opportunity to its population. CAI would enhance this strength. Because of its small, somewhat dispersed population, there is some difficulty in developing large institutional staffs for education in Alberta. CAI would allow greater dispersal of available instructional expertise. A major application of CAI could be retraining of labor to adapt to CAD/CAM technology applications.

Downstream Benefits. Downstream benefits of CAE include:

- Lower education costs
- More widespread access to information
- Access to current information
- More enjoyment and motivation for young people to learn
- Custom-tailored, learn-at-own-pace instruction
- Alberta products and services.

State of the Art. CAI software has been widely developed on a large variety of subject matter, and is readily available. However, much of the CAI software which could be obtained would have to be altered to suit the needs of Alberta. Of course, CAI software has not been equally developed in all areas, so Alberta would have to develop some software.

Data Bases

Definition. Data bases store and retrieve data on a computer. Most data bases are related to a specific application or industry, for example, an agriculture data base, construction data base, etc. Data bases provide the ability to rapidly access a large variety of timely, factual data. This capability is critical to certain industries such as construction, architecture and engineering and farming.

Application to Alberta. In order to compete in a world market and in order to improve productivity domestically, industry in Alberta needs rapid access to basic information necessary for conduct of business. In many cases, this necessary information is not readily available in Alberta. For example, market forecasts for products, construction, architectural, engineering, natural resources management, geophysical services and agriculture are a few examples of sectors needing data bases. Many data bases are available in agriculture. Networks are being set up to disseminate the information to farmers. Some of the data is available in private companies - e.g., oil industry. Some is available through other sources, e.g., agriculture. However, very few data bases are widely available to a user. Two firms with access to a large number of data bases are SOS Search Service, Santa Monica, California, and DIALOG Information Services, Palo Alto, California. A list of data bases is in Appendix F.* With access to the data bases, productivity increases are possible.

Downstream Benefits. Downstream benefits of data bases include:

- Improved response to requests for bids in architecture, engineering, and construction (AEC)
- Improved operational efficiency in agriculture and AEC
- Improved market knowledge for improved decision making.

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* From DIALOG Information Services, Inc., January 1983.

State of the Art. Many data bases are available; however, many are not accessible from Alberta. Some of the existing data bases are proprietary. Construction of a data base and access network is a major task. Data need to be collected, organized, and put in memory. A host system may be necessary, then an access methodology needs to be developed, including subscription, tie to an existing network, etc.

Automated Manufacturing Plants

Definition. This opportunity is the application of flexible computerized automation to manufacturing. Three basic elements are present in an automated manufacturing plant: processing equipment, material handling/ storage equipment, and the control system. Automated manufacturing plants are created by integrating individual pieces of equipment and software into a pre-planned, plant-wide information and work flow structure.

Application to Alberta. Alberta has many small factories and plants, relatively new buildings, a shortage of skilled labor and imports many finished goods. To supply the domestic market, a variety of flexible factories could be required. Several trade or vocational schools are present which could supply some of the skilled labor in the reasonably near future. Also, since smaller labor forces would be required, the impact on labor could be considerable. The smaller automated factories could be somewhat distant from major population centers. Examples of factories are metal fabrication, plastics, foundries and food.

Downstream Benefits. Downstream benefits of automated manufacturing include:

- High productivity of labor and capital
- High quality production
- Flexibility to meet changing demand for products
- Reduced lead times, improved responsiveness to demand
- Potential locations away from large population centers.

State of the Art. Technology is available for creating automated manufacturing plants, for example, flexible manufacturing systems (FMS) and automated storage and retrieval systems (AS/RS). A large amount of up-front planning and engineering are required, however, to ensure that all the pieces of the automated factory are integrated in terms of work flow and information flow. Automated manufacturing is easiest when a small variety (size, shape, and processing requirements) of products are manufactured.

Planning and Project Management

Definition. Planning and project management systems partially automate the management of large one-time projects. Planning and project management is very similar to operational management, except there is a much higher degree of risk in the schedule and budget. Planning and project management systems, which are well suited to architecture and engineering, construction, and community planning, can help with schedule, budget, facilities design, and material lists. Planning and project management is useful both for planning and for monitoring large projects and in training of project managers. Table F-2 has examples of companies' marketing programs.

Application to Alberta. Alberta has many companies in architecture, construction, and related industries. A few are doing foreign projects. Many are not using the full capability of management programming. Use of latest techniques would allow companies to be more competitive and more productive both domestically and on the world market.

Downstream Benefits. Downstream benefits of planning and project management systems include:

- More efficient construction operations - reduction of inventory, timely arrival of material, anticipation of problems
- More projects on time and within budget
- Reduced municipal planning cost.

State of the Art. Many planning and project management systems are available and many of these are designed for a specific industry (e.g., construction). The algorithms used in planning and project management are generally based on activity network models, with deterministic or probabilistic activity time periods. Systems are sometimes linked to a graphics terminal to allow graphical construction and presentation of networks, data, and results.

Hazardous and Unpleasant Environments

Definition. Many methods have been developed to allow man to operate in hazardous and unpleasant environments. This opportunity deals with two methods: sensors and manipulators/robots. Sensors can be used for early warning of an impending hazard, or to disable operation of equipment if men or objects enter the motion path of the equipment. Manipulators/robots can be used to remove humans from the environment.

Application to Alberta. Alberta has many industries in which some activities are hazardous. Specially designed robots and more sophisticated monitoring systems could either remove humans from the environment or reduce the exposure. Also, some of Alberta's industry is in cold climates in northern areas. Humans could be housed in a more protective environment and use robots in the unpleasant areas.

Downstream Benefits. Downstream benefits of sensors and robots in hazardous environments include:

- Improved safety, reduced insurance cost
- Reduced operating cost where labor cost is high (robots)
- More enjoyable work environment

State of the Art. Mining sensors for methane, CO, CO_2, fire, and explosive dust have been developed. Ultrasonic sensors have been used for detection of humans/objects in path interference. Robots and manipulators, of course, have been extensively used in manufacturing. Robots have seen limited applications on oil rigs. Other applications such as forestry, agriculture and mining are unfeasible at the present time because of the unstructured environment and the need for mobility.

Energy Management

Definition. Energy management systems are automated systems which control energy usage in buildings and equipment. Energy management systems can be employed in numerous applications, including offices, factories, refineries, mines, homes, and heavy equipment. Energy management systems attempt to provide the minimum energy required to maintain a pre-set level of service. Computers are valuable in energy management because they can provide repeatable, centralized control over a large number of parameters (related to energy use) in real time.

Application to Alberta. This opportunity is applicable to Alberta for several reasons as follows.

(a) Alberta is a resource province and a great deal of energy is utilized in extracting resources. Previously this energy was considered to be cheap. It can now be a reasonable cost. Industries which could benefit are surface mining and syncrude processing.

(b) Alberta also has much heavy equipment usage, large buildings, process plants, and factories. All could benefit from minimizing energy use.

(c) Alberta has a knowledge of the energy industries and some hostile climatic conditions. Systems need to be tailored to fit Alberta.

Downstream Benefits. Downstream benefits of energy management systems include:

- Large energy cost savings
- Potential export sales of energy management systems, software, and services
- Lower production cost in product and process industries
- Lower extraction cost in oil and mining
- Lower agriculture production cost (tractor energy control).

State of the Art. Present energy management systems are mainly for office or factory heating, ventilation, and air conditiong (HVAC) and lighting control. These systems operate by sensors such as thermostats, and by schedule, for example, vacancy of certain rooms at certain times. Energy management systems for process control and for heavy equipment are not as well developed due to more complex sensory and logic requirements.

Special Real-Time Signal Processing

Definition. This category deals with a variety of applications, all of special interest to Alberta. These applications involve a vast amount of data processing for correlation and/or presentation of large strings of sensed data. Examples include:

- Re-evaluating siesmic data records
- Simulation of reservoirs, pipelines, or processes
- Image processing of satellite data
- Molecular analysis and medical analysis.

Application to Alberta. Alberta has at present considerable capability in this area. Calgary has a large concentration of large computers and skilled users. Some systems are being sold from Alberta. Additional application is possible, e.g., in medical data reduction. Some of these systems require custom integrated circuits. These could be designed in Alberta and a larger market developed.

Downstream Benefits. Downstream benefits of special real-time signal processing include:

- Better resource management
- New medical diagnostics products for export
- Cost reductions in medicine and natural resources.

State of the Art. Application of this type of real-time signal processing requires high-capacity, high-speed computers. The computers and software required for those applications are generally available. However, custom integrated circuits are frequently required for specific applications.

Material Usage Optimization

Definition. Material usage optimization refers to automated systems which divide up raw stock into sets of pieces which minimize waste. Material usage optimization systems can be used in a variety of industries, including lumber, glass, meat, and sheet metal fabrication. The objective in material division is to satisfy the demand distribution for the various cut pieces. The constraint in material division is the size and shape of the incoming raw stock, which may or may not be selectable. Computer algorithms have proven to be valuable in material usage optimization because these algorithms systematically review numerous cutting or division patterns versus the objectives and constraints, as compared to the intuitive judgement used by a human. However, human judgement can frequently improve the output of material usage optimization systems.

Application to Alberta. Material usage optimization is important to several industries now. Included are metal fabrication, lumber and meat cutting. Optimizing material usage is particularly pertinent to custom job shops and plants in which demand can frequently dictate changes in cutting patterns. Alberta has many small companies with variable products which could also benefit. Optimizing material usage shows up as a productivity improvement in two ways: (a) lower material costs and (b) labor savings. Alberta could profit in both ways. Also, more latitude would be allowed in product pricing.

Extension of initial principles can apply to most manufacturing plants. Simpler initial systems could be integrated to more complete plant automation later.

Downstream Benefits. Downstream benefits of material usage optimization systems include:

- Reduction of waste
- Better satisfaction of demand
- Time savings in designing cutting or nesting patterns
- Reduced die design time, if linked to CAD for die design
- Reduced power saw setup time, if linked to automated saw.

State of the Art. Material usage optimization algorithms can be placed into two broad categories. The first category is iterative search, in which the algorithm starts with a pattern which is feasible (satisfies constraints), then moves through various improved patterns seeking the optimal solution. The second category is classification, whereby standard patterns are linked to specific combinations of incoming stock and outgoing demand. Description of the raw stock must generally be input manually to the material usage system, because existing sensors technology is not sufficiently advanced to automatically caputre the descriptive data in real time.

Technical Opportunities

Products, applications, and R&D opportunities were identified for six broad industry/sector categories. In many cases, the products would be produced in the manufacturing sector even though the user would be in a different sector. In Table 8 examples of specific opportunities are listed. Again, it is emphasized that other opportunities probably exist in each category.

Many specific opportunities for Alberta are contained in each broad opportunity area. Tables 9, 10, and 11 show specific opportunities, organized into application, product, or R&D categories, respectively.

Analogies to many of the technologies defined in the terms of reference have application to existing industries in Alberta. Appendix C is a listing for the following industries:

TABLE 8. EXAMPLES OF INDUSTRIES TO WHICH SPECIFIC OPPORTUNITIES APPLY

	Type Opportunity(1)		
Industry/Sector	Products	Utilization/ Application	R&D
Forestry	Resource Management Mapping Software	Resource Management Data Bases Optimized/Log Use Log Cutting	Resource Management Fire Detection Sensors
Agri Business	Farm Electronics Sensing & Monitoring Equipment Management Software	Farm Management Herd Management CAD Meat Cutting Robot Bone Extraction	Sensors Tractor Efficiency Robots
Manufacturing	Plant Simulation Small Automated Plants Farm Electronics Oil and Gas Electronics (Sense & Monitor)	Small Plant Design Material Optimization Productivity Tools and Software	Sensors for Many Applications
Mining Oil & Gas	Analysis Software Data Bases Mapping Data Bases Logging Software and Data Bases Down Hole Electronics	Cross Correlation Geophysical Data Processing 3D Presentation Computer Aided Mapping Robots	Sensors Geophysics Image Processing Sub-Surface Material Analysis Exploration Data Analysis Robots
Service/Utility	Education Software Productivity Software	Resource Management Data Base Energy Management Security Systems Remote Read and Monitor Equipment Occupational Computer Aided Instruction Remote Education Productivity Software	Medical Electronics Productivity Software
Construction	Civil Engineering Data Base	Sketch and Drawing CAD for A&E Robots	Civil Engineering Data Base A&E Project Management

(1) Each column is independent. There is no relationship between items when going from one column to another.

TABLE 9. APPLICATION/UTILIZATION OPPORTUNITIES

Resource Management and Planning

- Mining
- Forestry
- Irrigation
- Data Bases
- Manufacturing Locations
- Information on Demography
- Resource Bases
- Exploration Data Bases

Agriculture/Forestry

- Log Cutting
- Optimized Log Usage
- Egg Farm Management
- Irrigation Water Flow and Control
- Farm Management
- Herd Management

CAD/CAM - Automated Factories

- Food Processing
- Welding
- Plastics
- Meat Packing
- Production Software
- Metals Fabrication
- Molding, Sash, Cabinet and Door
- Material Usage Optimization
- Food and Beverage Handling
- Automated Material Handling

Geo Physical Data Processing

- 3D
- Cross Correlation
- Computer-Aided Mapping

Building and Energy Management

- Maintenance
- Energy
- Security

Project and Resource Management

- Community
- Architect and Engineering

Remote Reading Monitors and Instrumentation

- Pipeline
- Distribution Lines
- Far North
- Utilities

Hazardous and Unpleasant Environments

- Oil Drilling
- Mining
- Slaughter House

TABLE 9. (CONTINUED)

Computer Aided Instruction

- Industry (Management)
- Remote Education
- Occupational Education
- Curriculum Management

Architecture and Engineering - Sketch and Design Software

Productivity Tools and Software

Image Processing - Medical Diagnostics

TABLE 10. PRODUCT OPPORTUNITIES

- Farm Electronics
  - Moisture Monitor, Seeding Monitors, Management Software
  - Load Cells, Spray Monitors
- Education Software
  - Curriculum Management
- Civil Engineering Data Base
  - Products, Codes, Materials
- Natural Resources Management
  - Software
  - Mapping
  - Projects and Software for Developing Nations
- Plant Simulation
  - Small Automated Plant and Complete Plant Projects
  - Plant Planning Projects
  - Productivity Software
- Mining Field Analysis Software
  - Computer Data Bases
  - Mapping Data Bases
- Oil and Gas Electronics (Sense and Monitor)
  - Logging Software
  - Logging Equipment
  - Down Hole Electronics
- Hazardous and Unpleasant Environment

TABLE 11. R&D OPPORTUNITIES

Civil Engineering Data Bases

A&E Project Management Systems

Sensors

- Welding
- Tool Wear (Down Hole)
- Safety Systems
- Lumber Grain and Grading
- Tree Type
- Moisture Analysis
- Chemical Analysis of Soil
- Medical Diagnostic

Tractor Efficiency

- Torque
- Wheel Slip
- Moisture Content
- Soil Type

Geophysical Image Processing

- Cross Correlation
- Seismic Data
- Custom Chips
- Mappings for Subsurface Information
- Well Log Data
- Reservoir Modeling

Medical Electronics

- Internal Inspection and Diagnostics
- Mobile Sensors

Resource Management

- Wood/Land - Fire Sensing
- Subsurface Materials Analysis
- Exploration Image Processing
- Productivity Software

Hazardous and Unpleasant Environment

- Robots for Oil Drilling, Mining and Logging

- Architecture
- Construction
- Agriculture
- Natural Resources
- Mining
- Forestry
- Manufacturing
- Services and Utilities

The software oriented application section of this report (Computer Aided Design, Manufacturing Planning and Control Systems, and Computer Technology) discussed the application areas. A brief summary of other technical opportunities follows for several of the CAD/CAM group of technologies. These technical areas are:

Robotics
Group Technology
Automatic Material Handling
Sensors and Control

In the following examples, potential applications are not separated by whether or not R&D is required for application. This was done in previous tables.

Manufacturing applications are not emphasized here but are covered in the 10-year forecast of CAD/CAM technologies and in the appendices on (a) Analogies and (b) List of Opportunities.

Robotics

Robots have potential uses in several resource related industries in Alberta. Productivity improvements and removal of humans from hazardous and unpleasant environments are two objectives. The following are specific examples:

Potential Application of Robots

Industry	Potential Application
Construction	• Manipulator for on-site materials handling • Assembly operations in Arctic areas • Pipeline assembly • Finishing concrete floors
Agriculture	• Bone extraction • Meat cutting • Tool control on tractors • Cattle handling for identification and medical care
Mining	• Excavation • Setting explosives • Testing mines for safety • Installing supports
Forestry	• Log handling • Tree cutting • Tree stripping
Services and Utilities	• Intelligent forklifts • Assistance to handicapped to and from wheelchair • Manipulator units for garbage collection

Automated Materials Handling

Several applications of automated material handling were identified. Examples in resource related industries are given in the following tabulation.

Application of Automated Material Handling

Industry	Application
Construction	• Intelligent cranes with data bases for building shape, material lifted, cable stress, etc.
Agriculture	• Grain handling alternatives (e.g., pipeline) • Meat packaging and labeling
Natural Resources	• Slurry pipelines
Mining	• Guided vehicles for coal transport
Forestry	• Saw mill material handling • Finished wood handling and packaging

Group Technology

Only limited applications of analogies to group technology were identified.

Potential Application of Group Technology

Industry	Application
Architecture	• Modularity of building parts and concepts
Natural Resources	• Design of "Up North" vehicles • Design of oil rig parts and systems

Sensors and Controls

Many applications of sensors and controls were identified. Only a few are noted here. For a more complete list, see Appendices C and E.

Application of Sensors and Controls

Industry	Application
Construction	• Temperature, humidity, etc. for buildings energy management • Loads on equipment • Security systems
Agriculture	• Crop maturity • Crop spoilage • Optimum power for tractor • Soil moisture • Soil analysis • Optimization combine to separation • Building monitors • Optimization of milk production
Natural Resources	• Seismic data • Water and chemical analysis • Drill bit wear • Well logging • Oil rig crownsaver
Mining	• Tool wear sensing • Mine products analysis • Gas sensors
Forestry	• Tree maturity • Fire • Disease • Tree density

APPENDIX A

A 10-YEAR WORLD VIEW OF CAD/CAM TECHNOLOGY AND BUSINESS

APPENDIX A

A 10-YEAR WORLD VIEW OF CAD/CAM TECHNOLOGY AND BUSINESS

This section of the report discusses the state of the art in CAD/CAM technologies and forecasts anticipated developments in CAD/CAM technologies and business markets in 1987 and 1992. Because most of the developments and implementations of CAD/CAM technologies involve manufacturing industries, the majority of this section of the report is concerned with CAD/CAM technologies applied to manufacturing facilities. However, CAD/CAM technology forecasts are made for nonmanufacturing industries of particular interest to Alberta.

This section of the report is divided into four major segments, which are:

- CAD/CAM State of the Art - Manufacturing Industries
- CAD/CAM Technology Forecast - Manufacturing Industries
- CAD/CAM Technology Forecast - Nonmanufacturing Industries
- CAD/CAM Business Forecast

State of the Art - CAD/CAM Technologies

The state of the art in CAD/CAM technologies is discussed using the following seven major categories stated in the terms of reference:

(1) Computer Aided Design (CAD)
(2) Group Technology (GT)
(3) Manufacturing Planning and Control Systems (MP&CS)
(4) Automated Materials Handling (AMH)
(5) Computer Aided Manufacturing (CAM)
(6) Robotics
(7) Computing Technology

Computer Aided Design (CAD)

Computer Aided Design (CAD) systems partially automate the design process. CAD systems are applied primarily in four areas: mechanical parts design; electronic components design; architecture, engineering, and construction (facilities design); and cartography (mapping). The main purpose of CAD systems is to increase the productivity of designers by freeing them from the time consuming and error-prone tasks of drawing and calculation. In fact, the calculation speed of the computer has enabled the design of complex items, such as large-scale integrated circuits (LSIs), which would not have been feasible without CAD.

CAD systems perform three major functions: geometric modeling, analysis/simulation, and production data generation. All three of these functions are made possible by software packages resident on the CAD system's computer. These software packages are frequently application-specific (i.e., tailored to address the needs of a specific application).

Geometric Modeling. A geometric model is a graphical and mathematical representation of an object on a CAD system. The three types of geometric models are wire frame, surfaces, and solids. Wire frame models, today's most common geometric model, represent objects as a series of interconnecting lines. Wire frame modeling is available in 2D, 2-1/2D (constant cross-section), and 3D. 2D wire frames are sufficient for wiring diagrams, maps, and orthographic projections of mechanical parts and structures. 3D wire frames can present isometric views.

Wire frame models cannot provide information about surfaces of the object or distinguish between the interior and exterior of the object. This information is frequently necessary for NC programming or aerodynamic analyses. Surface modeling, whereby the object is represented by a collection of intersecting surfaces, is available to meet these needs. However, surface models require more computer memory and more calculations for model construction/manipulation than wire frame models.

Solid modeling is the ultimate visual and mathematical sophistication in geometric modeling. Solids modeling permits CAD design of complex objects which formerly required physical mock-ups. Solid models require extensive computational and memory capacity and extremely complex software. Solid models are generally considered to be necessary for integrated CAD and CAM mechanical part data bases. Solids modeling is currently emerging in commercial application, with perhaps 50 installations worldwide. The emergence of the 32-bit minicomputer, with its enhanced speed and capacity, will greatly facilitate the application of solid modeling, because the software is already well developed and the need for solid modeling is well accepted by industry.

Commercial solids modeling software packages include:

- Synthavision - developed by Mathematical Applications Group Inc. (MAGI). Versions are marketed by Control Data Corporation (called CDC-Synthavision), Applicon (called Solids Modeling), and CADAM

- Romulus - developed by Shape Data Ltd. and marketed by Evans & Sutherland
- TIPS - developed by Hokkaido University and distributed by Computer Aided Manufacturing-International (CAM-I)
- Geomod - General Electric CAE International
- Solidesign - Computervision
- DDM Solids - Calma

Analysis/Simulation. CAD analysis/simulation packages are obviously related to the CAD application area. Analyses/simulations in mechanical parts applications include calculation of physical properties, finite element modeling (FEM), assembly, kinematics, and systems analysis. Typical physical properties calculated include weight, volume, surface area, center of gravity, and moment of inertia. FEM analyzes the distribution of stress under loading throughout an object by (mathematically) dividing the object into small elements and estimating the stress on each element. CAD assembly allows the assembly of several parts in the graphics CRT to check for interferences. Kinematics allows animation of the motion of linkages. Finally, systems analysis is simulated testing of complex mechanical assemblies on the CAD system, using actual test data for some parts of the assembly and FEM data for other parts.

Analyses/simulations in electronics include circuit performance simulation, circuit logic simulation, and semiconductor processing simulation. Many extremely sophisticated analyses/simulations have been developed in the electronics industry because of the complexity of integrated circuits (ICs) and printed circuit boards (PCBs), and because of the high cost of prototype development and testing in the IC and PCB industries.

Production Data Generation. The most common form of communication between design and production is the engineering drawing. Drafting software in CAD systems performs automatic dimensioning, documenting, and formatting of final design drawings, using standard formats and notation from the specific field of application.

Two other means of communication between CAD and production are computer-aided process planning (CAPP) and NC parts programming.

CAPP. Process planning is the determination of production methods for a designed object. Computer aided process planning applies the computer to the process planning function. Research and development in CAPP has been directed mainly at the manufacturing industries. Process planning in the manufacturing industries involves selection of processes, machines, tools, operations, and sequences.

All CAPP packages now in existence are based on Group Technology (GT) classification and coding schemes. This type of CAPP is known as variant or retrieval CAPP. Using variant CAPP, the process planner interactively develops a GT code for a new part. This GT code is then used by the CAPP package to search a database for an existing process plan(s) for similar parts*. The existing process plan(s) is retrieved and then altered by the process planner to meet the specific requirements of the new part. Commercial CAPP software packages are:

- MIPLAN - marketed by the Organization for Industrial Research (OIR) and based on the MICLASS GT system.
- CAPP - developed by McDonnell-Douglas for Computer Aided Manufacturing-International, Inc. (CAM-I). CAPP is in the public domain.
- AMP (Automated Manufacturing Planning) - marketed by IBM

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* The ability to identify similarity of parts is inherent in GT classification and coding logic.

- AUTOPROS (Automated Process Planning System) - developed by NAKK project (Norway) and based on the TEKLA GT code.
- CAR (Computer Aided Routing) - developed by the Kansai Institute of Information Systems (Japan).

Another type of CAPP which is envisioned is generative CAPP. Generative CAPP would synthesize process plans for new parts from algorithms which define technological manufacturing decisions. Generative CAPP would be a form of artificial intelligence. It is doubtful that an all-encompassing generative CAPP could be developed for all manufacturing industries because of the complex variations between industries and facilities. However, a "semi-generative" CAPP package called Genplan has been developed by Lockheed-Georgia. Genplan, which was developed from CAM-I CAPP, employs a GT coding system (as do variant CAPP systems), but does not retrieve existing process plans. Instead, Genplan synthesizes a new process plan using a manufacturing logic developed specifically for the Lockheed-Georgia facility. Lockheed-Georgia developed Genplan by generating an in-house GT coding scheme, conducting a parts flow analysis, and inventorying the capacity and capability of all shop floor equipment in the facility.

NC Parts Programming. There are numerous NC processor languages, for example APT, ADAPT, ILP, PROMPT, etc., which simplify cutter location NC programming for the NC part programmer. A more sophisticated NC processor language is EXAPT, which automatically specifies cutting tools and machining parameters for the NC programmer. Additionally, most new CAD systems have the software to graphically verify the tool path from the NC program on the CAD system CRT. CAD systems can also generate the actual NC tape after graphical verification.

However, fully automated NC program generation from CAD geometric models can only be performed for flat parts, highly symmetric geometries, or certain specialized shapes. Automated NC program generation is available on CADAM from IBM and on CADD from McDonnell-Douglas. Another problem not yet solved involves developing an NC processor language to simplify the programming of generalized (non-mathematical) 3D surfaces. Current NC processor languages only handle mathematically definable surfaces.

CAD History. CRT graphics was first demonstrated at MIT in 1950, but it was not until 1962 that MIT developed a workable method for interactive graphics manipulation. The development of interactive graphics made CAD feasible and spurred large CAD development projects at MIT, General Motors, Bell Labs, and McDonnell-Douglas. Several firms specializing in CAD, such as Computervision, Applicon, and Calma, were formed in the early 1970's to meet industrial demand for turnkey CAD/CAM vendors.

Solids modeling software was first developed in the mid-1960's at several universities, including Berlin, Hokkaido, Cambridge, and Carnegie-Mellon. The first commercial solids modeling package was Synthavision, developed by MAGI for the Department of Defense for non-CAD purposes. Not until 1977 was Synthavision used for mechanical design. Several vendors offered versions of Synthavision beginning in 1980, and several internally developed systems were offered by CAD turnkey vendors in 1982. Approximately 5 commercial solid modelers were operating in industry in 1980, and about 50 are operating today, mainly for R&D functions. Heaviest use is in the automotive and aerospace industries.

In 1965 Lockheed-Georgia developed a computer system for documenting process plans. AUTOPROS, developed by the NAKK project in Norway, was introduced in 1969. In 1976, CAM-I CAPP was developed by McDonnell-Douglas under a contract from CAM-I. Six versions of CAM-I CAPP (which is in public domain) have been released to industry, one of which was to Lockheed-Georgia. Lockheed-Georgia's Genplan became operational in 1980. Less ambitious CAPP software packages (e.g., CAPP for a specific type of multi-purpose machine tool) are also becoming commercially available.

APT, the most basic and best known NC processor language, was developed by MIT in 1959 under an Air Force contract. APT was for mainframe computers, so in 1963 IBM introduced ADAPT for minicomputers, also developed on an Air Force contract. EXAPT was developed in West Germany and introduced in 1966. NC processor languages have proliferated tremendously.

Group Technology (GT)

Group Technology (GT) is a philosophy which asserts that industrial production can be simplified by grouping related components and/or processes to take advantage of similarities in design and/or manufacturing. GT systems are based on classification and coding systems which define components based on geometry, size, and/or process flow. The major benefits of GT are increased standardization of design and manufacturing procedures and reduced duplication of effort. Additionally, GT is necessary for all existing CAPP software.

The key to the success of a GT system is the classification and coding scheme. The classification scheme must group various components by characteristics which reflect the needs of the GT user. Components must be grouped in such a way that a specific component "family" represents a specific set of technological decisions in design and/or manufacturing. The code must accurately reflect the classification scheme so that a computer can easily retrieve "families" of components from a component data base.

GT codes are generally composed of a set of numeric digits, although alphanumeric codes exist. There are three general types of coding structures. The first is monocoding (or hierarchical coding), whereby the meaning of each digit is dependent on the value of the previous digit. Monocodes require few digits, but present difficulties for initial code construction and computer retrieval of part families. Polycoding is the next general type of GT code. In polycodes, each digit location represents a specific attribute of a part and all digits are independent. Polycodes are much easier for computer database retrieval, but need to be very long to sufficiently describe a part. Most current GT codes are hybrid codes, which have a mixture of monocode and polycode features.

Several GT systems are commercially available. None of these is universally acclaimed because of the difficulty of creating a single classification and coding scheme which reflects the needs of all industries. Any commercial system needs to be modified to match the needs of a specific company. Some of the commercial systems are:

- MICLASS - developed by TNO (The Netherlands) and marketed by the Organization for Industrial Research (OIR). MICLASS, the most popular GT system, is a 30-digit hybrid code. The first 12 digits represent basic "universal" part features, while the last 18 digits represent company specific information. The MICLASS software package is composed of a series of computer retrieval and analysis routines, one of which is the MIPLAN CAPP routine. MICLASS part codes are developed interactively by answering a series (10-15) of questions about the part.
- Brisch System - developed by E. G. Brisch (England) and available through Brisch, Birn & Partners, Inc. Basic version is a 6-digit monocode. A version of the Brisch system called PNC was developed for General Motors.
- CODE - an adaptation of the Brisch system marketed by Manufacturing Data Systems (USA). CODE is an 8-digit hybrid code.
- OPITZ - 9-digit hybrid code developed by Dr. H. Opitz, Aachen, West Germany.

Other systems include the VUOSO system (Czechoslavakia), the K-1,2 system (Japan) and the TEKLA system (Norway).

GT History. GT was first proposed in 1946 by S. P. Mitrofanov of the USSR. In the 1950's GT was developed by Mitronov (USSR), Opitz (West Germany) and Brisch (UK). However, GT was not feasible for general industry until MICLASS, a commercial, computer-based GT system was introduced in 1975.

Manufacturing Planning and Control Systems (MP&CS)

Manufacturing Planning and Control Systems (MP&CS) apply the computer to the management of industrial firms. There are currently about 80 vendors offering over 130 MP&CS packages. Some packages offer both hardware and software and others are software only. The most comprehensive MP&CS packages currently available are generally known as closed-loop Manufacturing Resource Planning (closed-loop MRP or MRP II).

Closed-loop MRP is generally composed of 10-15 modules, which cover seven basic application areas: bill of materials processing (BOMP), materials control, materials requirements planning (MRP), process and routing, capacity requirements planning (CRP), purchasing control, and shop floor control (SFC). These application areas are described below:

- Bill of Materials Processing (BOMP) - a list of materials, components and subassemblies needed for each final product.
- Materials control - monitors, plans, and records all in-house material flow, including receipt, inspection, storage, and release for work orders.
- Materials Requirements Planning (MRP) - determines what material will be needed, where and when it will be needed, by using BOMP and the master production schedule* (MPS)
- Process and Routing - defines work to be done, sequence of operations, and specific work center assignments
- Capacity Requirements Planning (CRP) - determines labor and equipment resources needed to perform MRP schedule and compares to resource availability.
- Purchasing control - plans reports on purchasing activity by vendor, by purchase order and by part number.
- Shop Floor Control (SFC) - tracks and reports on the progress of released work orders.

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* Schedule for end products; more description of MPS later in text.

The phrase "closed-loop" refers to the replanning capability of MRP II-type MP&CS packages. The various control modules report exceptions from planned execution back to the planning modules. The planning modules then "replan", taking into account the new situation on the shop floor, in materials and/or in purchasing (see Figure A-1). This feedback loop takes 24 to 48 hours in most current MRP-II type software.

The seven basic application modules just described provide computer-aided production planning and control. More sophisticated MP&CS packages have additional modules to provide computer-aided planning and control for all company functions. These modules are: forecasting, customer order servicing, master production scheduling, financial, and distribution requirements planning.

- Forecasting - projects sales volume
- Customer order servicing - processes customer orders
- Master Production Scheduling (MPS) - develops schedule for end items, considering sales forecasts, customer orders, and rough capacity requirements; attempts to smooth production
- Financial - through links with customer order servicing, shop floor control, material control, and purchasing control, the financial module maintains accounts receivable, accounts payable, work order processing, and payroll.
- Distribution Requirements Planning (DRP) - determines when end products need to be shipped, what resources will be needed for shipping, and compares needed resources to available resources.

Only about 75 companies worldwide have implemented an MP&CS package which has integrated all the previously listed features. These firms are known as Class A MPR II users.

Simulation. Computer simulation models are mathematical models of real, complex systems. Simulation models are used to hypothetically predict the effect on the system of changes in system variables. For

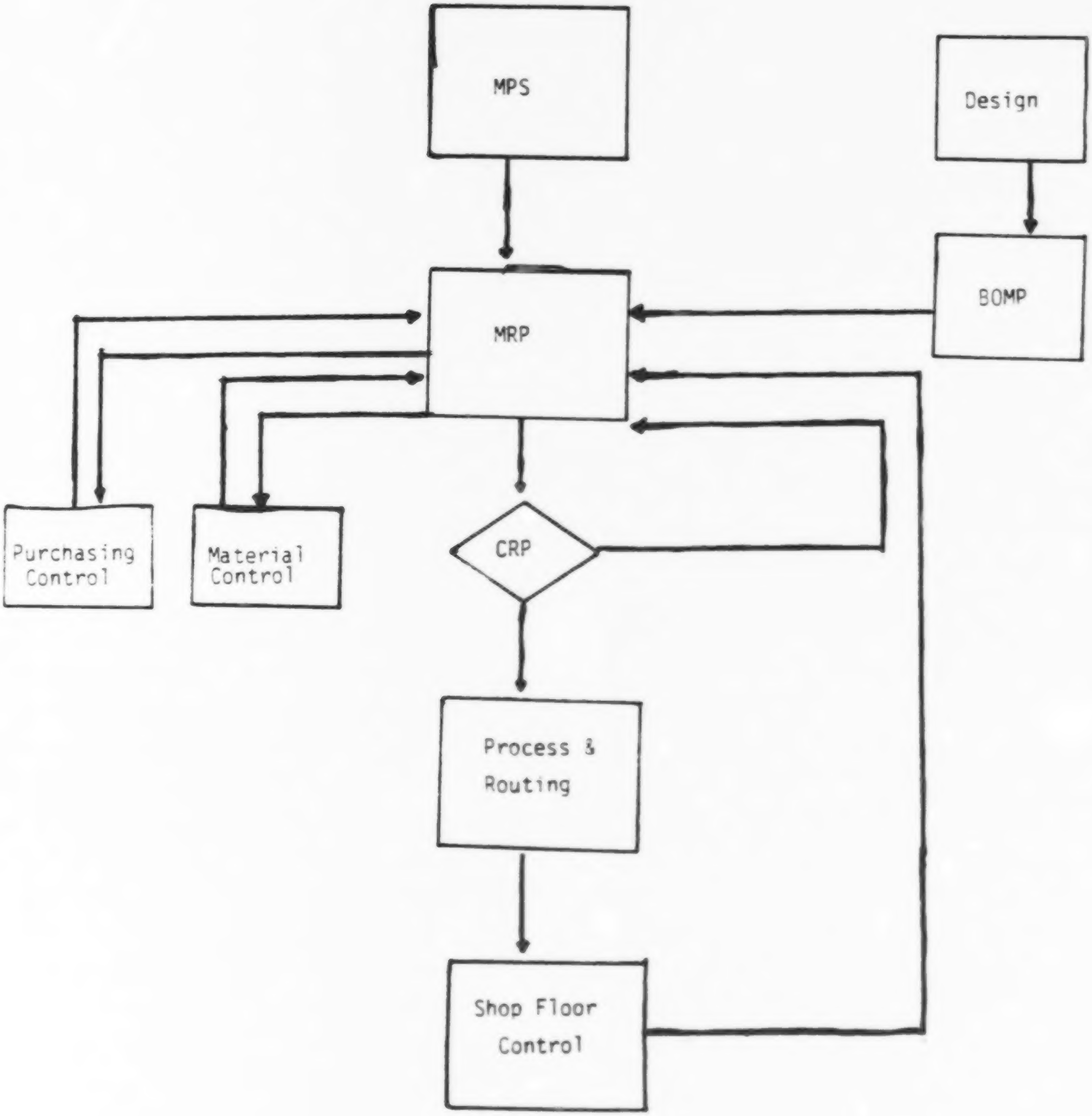
MPS
Design
MRP
BOMP
Purchasing Control
Material Control
CRP
Process & Routing
Shop Floor Control

FIGURE A-1. BASIC MRP II SCHEMATIC

example, simulation can be used to predict effect of various loads on a physical object, or the effect of various management procedures on the performance of a manufacturing facility. Therefore, simulation models are used for design, procedural analysis, and performance assessment.

There are two basic types of simulation models, which are:

- Discrete models - the value of system variables can be changed (independent variables) or predicted (dependent variables) only at discrete points in time. This is the less sophisticated form of simulation model.
- Continuous models - system variables can change continuously over time. The system is represented by a set of equations.

Continuous models are difficult to develop and are only developed when real-time automated control is necessary, such as in equipment or process control. Discrete models, which are less costly to develop, are used for designing and experimenting with systems where control is required at discrete points in time (at event completions), such as automated storage and retrieval systems (AS/RSs) and flexible manufacturing systems (FMSs).

The latest versions of MP&CS combine simulation and MRP II models. This allows management to play "what-if" games to select a best plan of action. Management can simulate manufacturing system performance given changes in sales forecasts, inventory levels, lot sizes and lead times. About 20 companies have an MP&CS package with this capability.

MP&CS History. Materials Requirements Planning (MRP) was first developed in the early 1960s by 5 companies in Racine, Wisconsin (USA). The original MRP concept was basically for inventory reduction only. The core assumption for MRP was that once the end product schedule was set (Master Production Schedule) all materials, components, and subassemblies requirements (timing and amount) could be predicted exactly using bills of materials and manufacturing lead times. The materials, components, and subassemblies were known as dependent items because the requirements for these items were directly dependent upon the requirement for the end products (independent items). The goal of MRP was to plan safety stock for end items only, thereby reducing inventory for most dependent items.

The first MRP II-type MP&CS packages became available in the early 1970s. An early example is COPICS from IBM, first marketed in 1972. MRP II/simulation packages were developed in the late 1970s.

Automated Materials Handling (AMH)

Automated materials handling (AMH) takes many shapes and forms in current state-of-the-art technology. Some of these many forms are: automated storage and retrieval systems (AS/RS), industrial trucks, conveyors, and automated guided vehicles. These variations of AMH will now be discussed. It is important to note that computer simulation is almost invariably used in the design of all AMH systems. Design of an AMH involves layout design, selection of equipment, and development of control procedures.

Most AMH systems are structured for hierarchical control. In a complete, generic hierarchical structure, a master computer specifies input and output requirements for the entire AMH system. An operations computer receives these directions and schedules movements of various pieces of equipment. Each piece of equipment, controlled by an on-board microprocessor, executes the directions of the operations control computer.

Automatic Storage and Retrieval System (AS/RS).

An AS/RS is an assemblage of equipment and controls that partially automates warehousing activities. An AS/RS is a high throughput, high density, and high security storage and retrieval method. An AS/RS consists of four main elements - the storage and retrieval (S/R) machine, the facilities, the conveying system, and the control system. The S/R machine automatically moves loads between an external staging area or conveying device and various storage locations. The facilities include the racking and the building. The conveying system moves loads to points outside the boundaries of the S/R machine. Conveying devices include lift trucks, conveyors, driverless vehicles, and tow-line carts. The control system is generally distributed and hierarchical. Various pieces of equipment are controlled by PCs or microprocessors, and a minicomputer usually directs overall operations.

Industrial Trucks. There are currently three basic categories of computer aid for industrial trucks. The simplest category involves computer-developed picking lists for manually operated trucks. The computer attempts to optimize facility throughput by directing the truck operator. The next level of computer aid for industrial trucks is on-board terminals. On-board terminals allow real-time direction of the truck operators, immediate verification of each pick made by the truck (through bar code readers or manual keyboard input), and the collection of productivity and maintenance statistics for each truck. The most sophisticated category of computer aid for industrial trucks is unmanned trucks. An on-board microprocessor controls the truck and receives directions from a master computer by FM radio signal or through an induction guide wire. Unmanned trucks are guided by rail or by a guide wire in the floor. Unmanned trucks maintain less throughput and cannot stack racks as high as AS/RS, but unmanned trucks can be used with standard racks, can be developed by conversion of conventional trucks, and can be installed and debugged in a relatively short period of time (approximately six months).

Conveyors. Computer aided conveyor systems generally encompass four major types of equipment: conveying equipment, input devices, sortation equipment, and a master computer. Conveyor equipment variations include accumulation, belt, magnetic, pneumatic, power and free, powered roller, gravity roller, skate wheel, towline, car-on-track, monorail and trolley. Input devices include manual keyboards, scanners, and sensors. Sortation equipment includes diverters, deflectors, pullers, pop-up rollers, belts or wheels, and moving slats.

In operation, the input devices identify the items on the conveyor for the master computer. The computer then directs the sortation devices to deliver the proper items to the proper locations. Conveyors delivering items to be shipped can terminate at automated palletizers and automated stretch wrappers.

Conveyors are generally for high volume operations and are relatively inflexible. However, in tow-in-line cart, car-on-track, and monorail systems, individual carriers can be added or removed to increase or decrease the capacity of the system. Additionally, car-on-track and monorail carriers are variable speed devices, independent of other carriers on the same system.

Automated Guided Vehicles (AGVs). AGVs are self-powered vehicles with sensors which enable them to track an energized guide wire in the floor. The AGV, which may or may not have an on-board microprocessor, receives direction from a control computer through the guide wire. AGVs are similar to unmanned industrial trucks without lifting masts or forks.

AGVs can be used to haul trailers, carry unit loads between pick-up and drop-off stations, for small parts material handling, and as a mobile assembly station. AGV systems are very flexible. Guide wires can be laid in the floor at a relatively low cost compared to conveyor equipment. Individual AGVs can be added or deleted from the system. AGVs are self-powered and therefore independent, variable speed devices. However, AGVs cannot match the throughput of most types of conveying equipment.

Computer Aided Manufacturing (CAM)

CAM refers to computer-aided control of equipment used for machining, fabrication, inspection, assembly, and testing. This discussion is divided into two CAM application areas: NC (numerical control), CNC, and DNC; and flexible manufacturing systems (FMSs).

NC, CNC, and DNC. Numerical control (NC) is simply the control of a piece of equipment by a symbolic code. An NC control unit is composed of electronic circuitry which translates symbolic NC instructions into specific actions by the NC machine. An NC program is a set of symbolic instructions which direct an NC machine to perform a series of operations upon a workpiece. NC allows flexible, programmed control of a machine tool.

A schematic of an NC system is shown in Figure A-2. The NC program is written on some media, generally punched paper tape, which can be read by the NC control unit. The control unit translates the NC program into an output signal which directs the machine tool to perform the required actions. NC is a closed-loop control system, whereby sensors on the machine tool feedback the actual performance of the machine tool to the control unit.

A normal NC control unit has hardwired electronic circuitry. Computer Numerical Control (CNC) adds a minicomputer to the control unit. CNC adds features to an NC machine tool such as:

- Stored NC programs - NC input media does not have to be read each time a workpiece is processed.
- Shop floor editing - NC program errors can be corrected at the machine tool
- Software is available for sophisticated interpolation, for calculating tool and fixture offsets, for post processing*, and for many other functions.

Virtually all NC machine tools built since 1977 have been CNC.

DNC (Direct Numerical Control or Distributed Numerical Control) links a master control computer to several NC or CNC machine tools. This allows downloading of NC programs directly to the NC control unit, circumventing the need to read input media at the machine tool. DNC also performs centralized functions such as scheduling of work on machine tools and data collection on machine tool status.

Flexible Manufacturing Systems (FMSs). An FMS is a collection of machine tools linked by a material handling system which manufactures several different workpieces. FMSs consists of three basic elements: The work stations, the material handling system, and the control system.

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* Post processing is altering the output from a general processor language, such as APT, to a form acceptable to a specific machine tool/control unit combination.

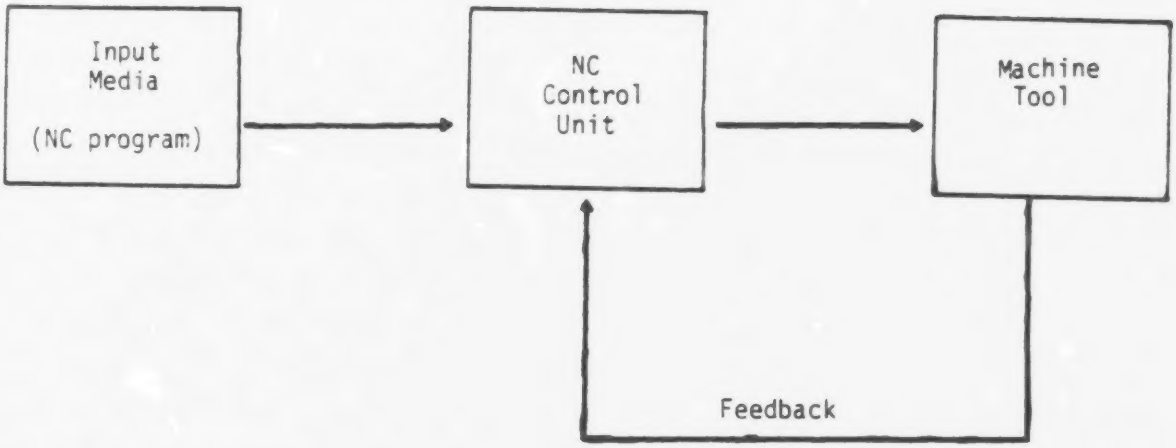
Input
Media
(NC program)
NC
Control
Unit
Machine
Tool
Feedback

FIGURE A-2. NC MACHINE TOOL SCHEMATIC

The work stations are usually machine tools, machining centers, or head-changers under direct numerical control (DNC). Other work stations are wash stations and gaging stations. The material handling system transfers work between load/unload stations and work stations. Sometimes shuttles are attached to each work station to transfer parts between a central delivery system and the work station. Typical material handling systems include tow-line carts, roller conveyors, car-on-track conveyors, and/or automatic guided vehicles (AGVs). Automatic storage and retrieval systems (AS/RSs) have been used less frequently. Given small parts, robots are frequently used to load parts from the delivery system to the work stations.

The control system monitors, controls, and schedules parts on the FMS. The control system contains decision-logic developed to sequence and dispatch parts to selected machines. This decision-logic is generally developed by exercising a simulation model of the FMS. Given a hypothetical set of operating conditions, the designer will test various tactics and select the set of tactics that results in the best operation of the FMS. Obviously, if an unexpected set of operating conditions arises during the actual operation of the FMS, the decision-logic may be ill-prepared to handle the situation.

A set of parts for an FMS must be similar in size, material, and required machining processes and each part must be subject to periodic, mid- or low-volume demand. The parts must be similar because current work stations, material handling systems, and particularly current control systems cannot handle a high degree of variety. If parts are subject to high volume demand, dedicated transfer lines are more cost effective than FMSs due to more rapid cycle times and higher accuracies.

CAM History. The first NC machine tool was constructed at MIT in 1952. The machining center, which can perform milling, drilling, tapping and boring operations, was introduced in 1958. The machining center is an NC machine tool with an NC-controlled automatic toolchanger. CNC was developed for in-house use in 1967 by the Strippet Division of Houdaille Industries (USA). DNC was developed both by Bendix and by Sundstrand in the year 1968.

The first FMS was constructed by Sundstrand Aviation in 1969. The system combines 8 machining centers, 2 multi-spindle drills, and a power and free conveyor system. Kearney & Treker developed a more sophisticated system in the early 1970s which employed towline carts as a central material handling system and shuttles for machine tool loading/unloading. Yamazaki introduced the YMS-50 FMS in 1979 in which a mobile spindle head can access several tool magazines. Cincinnati Millicron's Variable Mission System using wire guided carts (AGVs) for material handling was introduced in 1981.

Robotics

Robots (flexible automation) are programmable manipulators employed to move materials or tools through a programmed set of points. Robots consist of four main parts: the manipulator or arm, the power source, the controller, and the gripper or hand. Robots have three types of power sources: pneumatic, hydraulic, or electric. Power actuation can be servo- or nonservo-controlled.* A variety of control devices are available, including air logic**, PC, or minicomputer. The gripper generally is specialized for a particular application, however in some cases it is changeable.

Four important characteristics of robots are the work envelope, payload, axis of motion, and programming method. The work envelope is the three-dimensional space that can be touched by the gripper. The payload is the maximum weight the robot can lift, which varies within the work envelope and with speed of motion. The axes of motion are the separate motions available to the robot. Programming methods to control motion are point-to-point and continuous path. Point-to-point robots are programmed to move to a set of points by a device called a teach pendant. Continuous path robots are programmed by leading the manipulator through a set of motions.

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* Non-servo actuation is equivalent to an on-off switch, that is, motive power in each robot axis is either fully on or fully off. Non-servo actuation valves are signalled to open by control devices and are signalled to close (upon reaching the desired position) by limit switches. Servo actuation permits control over the amount of motive power released to each robot axis and uses continuous feedback from sensors to determine the position of the manipulator.

** Air logic is analogous to electronic logic. Power is pneumatic rather than electronic, and circuitry consists of tubing and valves rather than wiring, relays, transistors, etc.

Recent developments in robotics technology, which are not yet being applied in general industry, are robotic vision, tactile robots, and off-line programming. Robot vision and tactile sensing have been employed in Japan since the late 1970s, but have not been applied outside Japan. However, Stanford Research Institute has developed Robot Programming Language (RPL) for linking robots to visual sensors and Charles Stark Draper Labs has developed Draper Industrial Assembly Language (DIAL) for linking robots to tactile sensors. Off-line programming of robots has been demonstrated by Unimation's VAL. McDonnell-Douglas developed the Manufacturing Control Language (MCL), which provides off-line programming for entire manufacturing cells (including robots) in 1981 as part of the ICAM program. Both Automatix and Computervision have commercial packages, introduced in 1982, which link off-line programming to a CAD/CAM database. Finally, IBM is developing the Automated Parts Assembly System (AUTOPASS), a high level robot programming language which would partially automate off-line robot programming, using a CAD/CAM database.

Robotic History. In 1954, a patent was awarded to G. C. Devol for a playback manipulator, which would become known as an industrial robot. The first commercially available robot was marketed by Unimation (USA) in 1960. Robot tactile systems were first demonstrated by Versatran (USA) in 1971 and robot vision systems were first demonstrated by Hitachi in 1973.

Computing Technology

Advances in computing technology have been key to the development and advancement of all CAD/CAM technologies. Improvements in miniaturization, calculation speed, ruggedness, energy requirements, and cost/capability ratio have made possible applications such as CNC, on-line MRP II, and solids modeling, as well as many others. The following discussion of state of the art in computing technology will cover these topics: microprocessors, programmable controllers (PCs), data storage, and networks.

Microprocessors. A microprocessor is a central processing unit (CPU), random-access memory (RAM), ready-only memory (ROM) and shift register on a single integrated circuit. Microprocessors were made possible by large-scale integration (LSI) technology, a CAD/CAM method for producing extremely small electronic circuits on a silicon chip. Even higher density chips are now being produced by a technique known as Very Large Scale Integration (VLSI). Rapid improvements in circuit integration have been the rule in the 1970s, and this trend is expected to continue in the 1980s, as shown by the results of a Bradly University study, shown in Table A-1.

Another trend in microprocessors is increasing CPU word length. Increased CPU word length greatly extends microprocessor calcualtion speed. 8-bit CPUs, which can hold eight binary digits at a time, are relatively inexpensive and satisfactory for most equipment control applications. 16-bit CPUs had been the high performance standard, but now 32-bit CPUs, which can process 5 million instructions per second, are becoming available. 32-bit microprocessors and minicomputers are being applied to speech recognition, vision systems, high resolution graphics, and as high-performance controls.

Programmable Controllers (PCs). PCs are ruggedized microprocessors designed for the shop floor. PCs were originally designed to replace relays for sequence control of equipment, and are therefore generally programmed using relay ladder logic. Over the years, PC capability has

TABLE A-1. CIRCUIT INTEGRATION IMPROVEMENTS

Active Devices per Chip

Year	Devices
1970	100
1975	4,000
1980	100,000
1985	1,000,000

Cost of equivalent CPU and memory

Year	Cost
1970	50,000
1975	10,000
1980	1,000
1985	100

Speed-power product

Year	Picojoules
1970	400
1975	40
1980	2
1985	0.2

Source: Bradley University

advanced from mere sequence control to new functions such as timing, counting and data storage, and data averaging for equipment motion control.

One problem with PCs is a relatively slow resonse time of 20 milliseconds, which prohibits the use of PCs for sequence control of high speed equipment or for most closed-loop control applications. In these situations, a microprocessor can be added to the PC to decrease the response time to less than 10 milliseconds.

Data Storage. The most easily accessible form of computer memory is random-access memory (RAM). 64-kbyte RAM is commonplace with current technology and 256-kbyte RAM is common but expensive. Less accessible memory options are disk and bubble. Flexible disks normally range from 100 kbytes to 1.6 Mbytes capacity with a high of 10 Mbytes. Hard disks normally hold 2 to 5 Mbytes, but advanced versions have a capacity of 2500 Mbytes. Bubble memory has not been applied to mainframe computing, but is frequently used in NC equipment because it is nonvolatile memory.

Local Area Networks (LANs). LANs allow commication between various devices in small areas, such as a manufacturing facility. LANs allow communication between PCs, microprocessors, minicomputers, and mainframes. Obviously, LANs are a key to integrated, real-time control of manufacturing facilities.

The right of a device to broadcast on the network is controlled by a communications protocol. This protocol may be administered by a single network controller, known as a hierarchical network, or it may be a function of all devices in the LAN, known as a peer-to-peer network. Connections in LANs are either pair-wire or coaxial cable. Cable is higher speed, less affected by electronic noise, and more expensive than pair-wire.

A major problem with current LANs is the difficulty of hooking up different vendors devices into a single network. Each individual vendor has a unique data format which prohibits communication with other vendors' devices without a translator. Major efforts to develop standard data formats are being conducted by the International Organization for Standardization, by the U.S. National Bureau of Standards, and by IEEE.

Computing Technology History. The first electronic computer was the ENIAC, built in 1947 by Westinghouse (USA). In the early 1950s, development work in printed electronic circuits was conducted by a coalition of the National Bureau of Standards and the U.S. Navy. Integrated circuits were first developed at Texas Instruments in 1958 and were being mass produced by the mid-1960s. One of the first on-line, real-time computer systems was used by American Airlines starting in 1962. The IBM System 360, introduced in 1965, became the standard for mainframes for a decade. In 1969, the first programmable controller (PC) was produced by Modicon (USA). A few years later, the first microprocessor was produced at Intel Corporation (USA). Current R&D in computing technology is directed at parallel processing for increased computational speed, new chip materials for increased miniaturization, and improved operating system software.

Development Programs

Future CAD/CAM technology is dependent upon current development programs. CAD/CAM development program in the U.S., Japan, and Western Europe will now be described.

U.S. The most significant development programs in the U.S. are those in the aerospace industry funded by the Air Force. Five major programs are being managed by the Manufacturing Division, Materials Laboratory, Air Force Wright Aeronautical Laboratories (AFWAL), namely:

- Air Logistics Command (ALC) - aimed at modernizing manufacturing facilities used by the USAF. ALC is funding an FMS program which is aiming for an operational, factory-wide FMS in 1986.
- Generic Manufacturing Technology - aimed at enhancing current manufacturing techniques

- Integrated Computer Aided Manufacturing (ICAM) - aimed at developing a CAD/CAM factory model, at enhancing technology transfer, and at developing a fully automated sheet metal fabrication center by 1986. The Group Technology Characterization Code (GTCC), a generic GT classification and coding scheme, is being developed in this program.
- Technology Modernization (Tech Mod) - aimed at modernizing USAF vendor's manufacturing facilities
- Manufacturing Science - a new program aimed at developing advanced manufacturing science and technology. Major thrusts are improving sensors and forging die design and fabrication techniques.

The National Bureau of Standards (NBS) is developing standard data formats for CAD and CAM data transfer. Standard formats for CAD data have been developed in the form of the Initial Graphics Exchange Specification (IGES). Standard formats for the real-time data transfer required for CAM applications are expected to be demonstrated in 1986.

Computer Aided Manufacturing - International, Inc. (CAM-I) is a nonprofit organization dedicated to the promotion of CAM technology. Major CAM-I programs are now dedicated to developing improved NC processor languages for sculptured surfaces and developing fully automated NC programming.

Japan. The major development program in Japan is the National Project, coordinated by the Research Association for Flexible Machining System Complex provided with Laser. The FMS complex is an experimental plant, to be commissioned in 1984, which will be a factory-wide, integrated FMS. The plant will have three main sections: material processing, machining-assembly-inspection, and laser.

University-level research at Hokkaido, Kobe, Tokyo, Kyoto, and Keio Universities is aimed at several technology areas. These areas, which are considered to be the major remaining barriers to fully unmanned manufacturing, are integrated CAD/CAM software, machine tool diagnostics, mobile repair robots, and flexible assembly.

Advanced research in Japan is aimed at developing metamorphic machine tools, which would actually change to perform various tasks. This would eliminate material handling and simplify process planning.

Western Europe. The highest level of research in Western Europe is directed at improving robotics technology. Major research areas include robot vision, robot mobility, improved gripper technology, and improved speed and accuracy of robots. Robotic research programs are being conducted at IPA Stuttgart (FRG), Linkoping University (Sweden), Federal Institute of Technology at Lausanne (Switzerland), Brown Boveri Research Centre and Warwick University (UK), and Laboratoire d'Automatique et d'Analyse des Systemes (France).

Western European development programs in CAD/CAM software and in FMS technology are aimed at standardization, modularization, and promotion of industrial use, as opposed to U.S. and Japanese efforts to expand technological capability. CAD/CAM software programs are ongoing at the Production Engineering Research Association and the Computer Aided Design Centre (UK) and at the University of Leuven (Belgium). FMS development projects are the British Automated Small-Batch Production project and various projects at Zahnradfabrik (FRG).

CAD/CAM Technology Forecast

CAD/CAM technology will be increasingly developed, enhanced, and applied in all major industrial countries over the next 10 years. This assertion is based on the following evidence:

- Computing technology is already sufficiently developed to handle virtually all foreseeable requirements of any CAD/CAM technology. Additionally, the cost/capability ratio of computing technology is decreasing exponentially over time.
- Skilled labor shortages are being experienced by all industrial countries. Skilled labor availability will continue to decrease, while the cost of all skill levels of manufacturing labor should continue to rise.
- The rising cost of capital is driving manufacturing firms to seek lower inventories and higher equipment utilization.
- Increasing worldwide industrial competition will drive firms to lower cost and improve quality.

In 1980, the University of Michigan and the Society of Manufacturing Engineers (SME) conducted a Delphi forecast study of CAD/CAM technologies. The study group, composed of technical experts from Japan, the U.S. and the U.K., predicted usage rates of various CAD/CAM technologies in the three countries. Some of the results of the Delphi study were:

(1) 25% of all machined parts designed on CAD
  - U.S. 1985
  - U.K. and Japan 1990

(2) 20% of industry using MRP and CAPP
  - Japan 1986
  - U.S. and U.K. 1990

(3) 50% of all paperwork to process assemblies done using computer
  - U.S. 1987
  - Japan and U.K. 1988

(4) 25% of all factories employing less than 1000 people will have implemented CAM
  - U.S. 1990
  - Japan and U.K. 1995

(5) 25% of instructional pictures for shop floor set-up and operation on graphic CRTs
  - U.S. and U.K. 1990
  - Japan 1995

(6) GT applied to 10% of all machining operations in companies employing less than 1000 persons
  - U.S. and Japan 1990
  - U.K. 1993

The ultimate application of CAD/CAM technologies would be an unmanned factory operation. However, there are several barriers to fully automating an entire factory. Some of these barriers are:

- Investment - extremely high investment is required
- Database - a database structure which provides sufficient information for design, manufacturing, assembly and testing (and management, marketing, finance, etc.) has yet to be developed
- Operating system - an operating system must be developed to manage the huge amount of data which would have to be processed for real-time control of a manufacturing facility.
- Sensors - improved vision and tactile sensors will be required for most automated flexible assembly operations. Flexible assembly applications are rare at the present time.
- Diagnostics and automated repair - removing maintenance personnel from the shop floor will be extremely unlikely in the next 10 years. Machine tool diagnostics are extremely primitive and automated repair is non-existent. Both diagnostics and repair would require highly developed sensors.

- Mechanical capability - the mechanical capability of robots must be improved. Robots need mobility and increased speed, accuracy and dexterity.

It is likely that the barriers of database and operating system will be solved in the U.S. within the next 5 or 10 years. The most significant progress in sensors, robot mechanical capability, and automated diagnostics and repair will most likely occur in Japan. Both Japan and the U.S. will undoubtedly have showcase factory-wide integrated CAD/CAM installations by 1987.

The problem of high investment cost to general industry is resulting in a trend towards standardization, modularization, and flexibility by both government programs and private vendors. Standardization allows the integration of software and hardware from several sources into a single system. Modularization allows low-cost design of CAD/CAM systems tailored to the user's requirements by combining "building blocks" of automation. Flexibility ensures that the CAD/CAM system will continue to meet the user's requirements as these requirements change over time.

Table A-2 shows more detailed forecasts for each CAD/CAM technology area for the years 1987 and 1992, as well as the historical development of these technologies.

TABLE A-2. CAD/CAM TECHNOLOGY FORECAST

	1950s	1960s	1970s	1980-82	1987	1992
CAD						
- Graphics & Modeling	• Computer Graphics developed (1953)	• Interactive Graphics (1962) • Solids modeling (mid-60s) • Commercial use of CAD graphics (1964 at GM)	• Solids modeling used for mechanical design (1977) • Turnkey CAD packages commercially available (1972)	• 50 solids modeling CAD installations (1983) • Large format, flat panel displays in use at universities	• High resolution, raster-scan (dynamic) graphics; CRTs are commercially available • Proliferation of specialized simulation/ analysis software for various applications	• Color raster-scan CRTs dominate market • Large screen & hand-held graphics CRTs commercially available • Solids modeling dominates market • Standard software packages are used for image generation & manipulation
-CAPP		• Process planning documentation by computer (1965 at Lockheed-Georgia) • AUTOPROS (1969 in Norway)	• CAM-I CAPP (1976) • MIPLAN (mid 1970s) • CAR (1975 in Japan)	• Genplan (1980) • Link-up of CAPP with computer graphics (1981 - MIPLAN on Computer-vision system)	• CAPP capability to develop assembly instructions (not commercially available; only at highly developed installations)	• Generative CAPP available for aerospace industry
-Part Programming	• APT (1959)	• ADAPT (1963) • EXAPT (1965)	• Specialized NC processor languages proliferate (1970s)		• Fully automated part programming from CAD database for simpler operations (up to 3-axis control) • Commercial NC processor languages for sculptured surfaces	• Fully automated part programming for virtually all parts and machine tools
GT	• GT development programs in USSR, W. Germany, U.K.		• MICLASS (1975)		• Generic GT code developed (for aerospace)-Group Technology Classification Code(GTCC) by ICAM	• Partially automated GT coding from CAD geometric model
MP&CS		• MRP (early 1960s) • Management Information Systems (MIS) (1960s)	• COPICS (1972) • On-line MRP (late 1970s) • Simulation used to develop control procedures for AMHs and FMSs	• MRP II/simulation	• Increased use-of simulation to develop manufacturing management procedures • Low cost simulation software for microcomputers available (US and UK) • Data-base independent MP&CS software • Increased linkups to shop floor networks	• Machine independent MP&CS software
AMH		• Development of AMH technologies (late 1960s) - AS/RS - AGVs		• Unmanned industrial trucks	• Customized AMH systems are dominant • Most systems use manual key code and bar code inputs	• Modular AMH components available • Increased use of bar coding and more sophisticated visual sensors

TABLE A-2. (CONTINUED)

	1950s	1960s	1970s	1980-82	1987	1992
CAM						
-NC, CNC, DNC	• NC (1952) • Commercial NC (1955) • Machining Center (1958)	• Commercial CNC (1967) • Commercial DNC (1968) (US, UK & Japan) • Adaptive Control (1968 at Bendix) • Programmable Controller (PC) (1969)	• Machine Tool Diagnostics (1974 from Kearney & Trecker)		• Commercially available in-process gaging using probes and/or lasers • Commercially available adaptive control (load or torque based)	• Metamorphic machine tools developed in Japan • Sophisticated machine tool diagnostics available
-FMS		• Operational FMS (1969 at Sunstrand Aviation)	• ROTA & PRISMA (1971 GDR) • YMS-50 system (1979 from Yamazaki)	• VMM system (1980 from Milicron) • 65 FMSs in US • 50 " " Japan • 30 " " W. Europe • 30 " " E. Europe	• Application of laser machines in FMS (Japan) • Delivery of tool magazines from central tool bin standard on most large FMSs • Several installations connect FMS to AS/RS	• All smaller FMSs composed of modular components • Sophisticated FMSs contain assembly and testing stations
Robotics	• Patent on Industrial robot (1954)	• Working industrial robot (1960)	• Robot spot-welding line (1970 at GM) • Robot Tactile sensor (1971 from Versatran • Robot vision (1973 from Hitachi) • Robot FMS (1977 at Cummins)	• 8000 robots in Japan • 5000 " " U.S. • 5000 " " W. Europe • 4000 " " E. Europe • Robot programming languages VAL&MCL • Link robot control to CAD/ CAM database (1983 Computervision & Automatix)	• End effectors which perform inspection • Adaptive control of robots • Modular robot components (Japan) • Proximity sensors for safety • Primitive tactile and vision sensors accessible to most firms	• "Human-like" tactile and vision sensors emerging commercially • High-level robot programming languages linked to CAD/CAM database
CIMS				• IGES for CAD graphics data interface	• IGES for real-time machine control interface • Commercially available integrated CAD/CAM database structure using solids modeling, CAPP, NC processor language, and robot off-line programming languages • Fully automated sheet metal fabrication center (ICAM - U.S.) • Fully automated manufacturing facility (National Project - Japan)	• Commercially available integrated CAD/CAM/MP&CS database structure.

TABLE A-2. (CONTINUED)

	1950s	1960s	1970s	1980-82	1987	1992
Computing Technology						
	• Eniac (1947) • Printed electronic circuit development (early 1950s by U.S. Navy) • Integrated circuit (1958 at Texas Instruments)	• On-line, real-time computing (1962 at American Airlines) • IBM System/360 (1965) • Programmable controller (1969 at Modicon)	• Microprocessor (early 1970s at InTel) • Local area networks (late 1970s)	• Proliferation of low-cost electronic products products with higher speed and larger memory	• Limited application of parallel processors • High-level languages developed (user-friendly) • Increased use of videodisk storage	• Vocal input to computer • Artificial intelligence is demonstrated for manufacturing management and robotics • Fiber optic LANs

CAD/CAM Technology Forecast - Nonmanufacturing Industries

The CAD/CAM technology forecast for nonmanufacturing industries discusses seven industries of particular interest to Alberta, which are:

- Farming
- Beef/Livestock
- Food Processing and Distribution
- Forestry
- Coal
- Bulk Handling
- Oil

Farming

1983
- Computer Management. Vendors have developed software for farm management. Various packages include:
    - feed management
    - grain management
    - fertilizer management
    - water management
    - storage requirements planning
    - data links to market pricing information.
- Equipment Control
    - Draft control by sensing force and speed. Then computer control of raising and lowering of implement
    - Computer-controlled grain crop planters which sense speed, seeding rate, and failure rate.

1987
- Computer control will be applied to tractor operation. Sensors will monitor transmission setting, drive wheel slip, implement position, etc., and optimize engine operating characteristics for
    - maximum work rate or
    - minimum fuel consumption.
- Computer controlled planting will have sensors for tractor speed and soil moisture content and to determine seeding rate and planting depth.
- Computer controlled harvesting will set operating parameters based on cutter height and moisture content sensors.

1992
- Sensors will be developed for organic matter content, clay or sand content, and fertilizer level. These sensors will be used for planting, fertilizing, irrigation, etc.
- Automatic tractor guidance by wire or radio signal will have been demonstrated, but will not be commercially available.

- Remote sensing will be routinely used for prediction of crop yield, advance warning of freezes, and monitoring of irrigation and insects.
- Outdoor robot farmers will be under development.
- Fully automated farming in controlled environments will be implemented in large metropolitan areas. Lettuce and perhaps tomatoes and cucumbers will be produced.

Beef/Livestock

1983
- Computer database management to aid management decisions.
    - farm operation
    - individual animal record-keeping and evaluation

1987
- Automatic identification of animals by passive transponder or magnetic stripe attached to collar or leg band.
- Automatic milk and egg yield recording devices will be used.

1992
- Implanted electronic devices will be used for automatic identification and physiological status monitoring.
- Computerized feed rationing will be linked to implanted electronic devices.

Food Processing and Distribution

1987 Most investment in CAD/CAM Technologies will be in MP&CS.

- Computerization of management and administrative functions such as inventory control, forecasting, order entry, purchasing, and production management.
- Computerization of warehousing management by computer generated picking lists, and of distribution by computer generated truck routings.

Less investment will be in AMH systems.

- Bar coding will proliferate in processing, warehousing, and retailing to effectively communicate with MP&CS.
- On-board terminals on industrial trucks and man-ride S/R machines for order-picking and picking verification.
- Specialized automated order-picking systems, sometimes called "vending machine-type" systems, will be employed for high-volume and/or frozen food operations.
- AS/RS will be used only by very high-volume processors and warehouses.

Other trends include:

- The Uniform Communication System (UCS) will be fully operational in the U.S., allowing electronic communication between various firms in the food industry.
- Automatic reordering will be implemented by many large food retailers as part of the UCS.

1992

- The drive for automation will force the standardization of packages (size and materials)
- Electronic shopping will become a factor in the dry goods and frozen foods markets
- A few fully automated plants will exist for producing and/or warehousing dry goods or frozen foods.
- Robots will be used for palletization and depalletization. There will be limited applications of robots used for order picking.

Forestry

Automation of forestry will be extremely difficult due to irregular shaped products and extreme variations in both weather and workplace conditions.

Computers will be applied to management of forestry, in the following areas:

- Scheduling
- Workplace Layout
- Forecasting
    - sales
    - equipment replacement
    - inventory
    - manpower
- Simulation
    - affects of variations in independent variables on profits and/or ecosystem
- Data Base Management.

Coal

1983

- Computer processing of seismic and electromagnetic exploration data
- Computer-aided design of mining facilities
  - mine
  - material handling and storage
  - cleaning
- Simulation of mining and reclamation operations. Available software packages are:
  - McDonnell-Douglass
  - MANTECH
  - SEAMPLAN (from Montana State)
  - OPMHS (from Penn State)
  - SMCALC (from Penn State)
  - Fluor Mining & Metal, Inc.
- Coal analysis software for moisture, ash, BTU and water equivalent, Escka's sulfur, etc.
- Microprocessor control, protection, and monitoring of large motors.
- Computer controlled cyclones and magnetic separators
- Sensors for methane, CO, CO_2, fire, and explosive dust.

Trends:

- Computer control of mining equipment for maximum work rate and minimum fuel consumption using force and speed sensors.
- Improvements in planning and management algorithms related to historical mine data, geophysical, topographical, and coal analysis data.

- Overall supervisory computer monitoring and control of all crushers, feeders conveyors, and reclaimers
- Continuous coal analysis sensors using radioactive bombardment
- Computer environmental and safety control system for the total underground mine operation using sensors and telecommunications equipment
- Computer-aided design of blast charge size and placement.

1992
- Robot mining machines and hauling trucks will just be under development in 1992.

Bulk Handling

Trends:

- Computer-aided design and simulation of bulk handling systems considering
  - material characteristics (density, moisture content, abrasiveness, etc.)
  - feed controls
  - particle degradation
  - space limitations
  - casing enclosures
  - system functions
  - capacity requirements
- Continued development of flow and level sensors using ultrasonic, electromagnetic and nuclear radiation. Linkup of these sensors to supervisory computer control.
- Computer control, monitoring and protection of drive motors.
- Computer control of feed and flow control devices.

Oil

1983

- Measurement while drilling (MWD) systems measure well bore inclination and direction.
- Computer data gathering systems record and display drilling parameters.
- Robot "Iron Roughnecks" and pipe racking devices have seen a limited number of applications
- Automated metering sites have seen a limited number of oilfield applications.
- Drilling simulator for training drilling operators.

Trends:

- Well logging
  - combination logging tools
  - increased use of data links and well-site processing
  - increased log accuracy to exploit marginal reserves
- Computer algorithms to process multiple logs, pressure measurements, seismic data, and geologic information
- Simulation used for drill path planning
- Database of individual well histories used for future well planning
- MWD
  - measure weight-on-bit and logging data along with survey data
  - well-site computing for real-time feedback control of drilling parameters
    - weight-on bit
    - tool change
  - optimal path calculation using historical database and sensed data
- Increased applications of iron roughnecks, pipe racking devices, and power swivels

- Fully automated oilfield through use of:
  - MWD
  - well-site computing
  - automated metering sites and valve control
  - iron roughnecks, power swivels, pipe racking devices
  - local area networks
  - overall management computer
  - simulation and analytic algorithms for planning and management
- Computer controlled remote subsea equipment for exploration and drilling
- Computer-aided design of offshore platforms and equipment.

CAD/CAM Business Forecast

The markets for all CAD/CAM technologies are expected to grow in the next 10 years. The following market forecast is divided into six market/application areas.

CAD/CAM Markets/Applications

The CAD/CAM markets involve several separate but interactive parts. Each of these submarkets will be addressed individually. The topics which will be addressed are:

- Flexible Manufacturing Systems (FMS) - From a user viewpoint participants in this currently small market are primarily very large multifaceted companies. While no totally automated factories presently exist, portions are present as flexible machine cells. The impact of FMS is in the changing way people think and act towards manufacturing processes. Vendors of FMS are primarily large machine tool manufacturers.
- CAD/CAM Equipment (Hardware) - Applications in this very diverse market range from limited simple design systems to large systems design and manufacturing control. CAD/CAM equipment is primarily design oriented at present. The manufacturing portion is restricted to use of CNC and NC machines. Vendors fall into three main categories: turnkey houses, mainframe computer manufacturers, and graphics equipment manufacturers.
- Automated Materials Handling Equipment (AMH) - This market is dependent primarily on development and growth of flexible manufacturing systems and CAD/CAM. As such, cells and systems are designed and introduced in the manufacturing process and will also be utilized in automated materials handling equipment. The traditional automated materials handling equipment vendors continue to be the primary vendors; they have been joined recently by large vertically integrated FMS manufacturers.

- Robots - Robots are considered by some to be another piece of materials handling equipment, and by others to be a machine tool. However, the technologies and vendors involved are sufficiently specialized to warrant separate attention. Vendors are both small companies manufacturing robots and large vertically integrated FMS companies.
- Software Systems - Of course CAD/CAM, robots, FMS, etc. require software systems of various types. However, of primary interest in the longer term for CIMS is software systems which facilitate utilization of manufacturing philosophies: group technology, materials resource planning, interactions of various subsystems, etc. Vendors in these markets are CAD/CAM vendors and users and independent software vendors who provide what is known as third party software.
- Communications Networks - Markets for communications and networks are dependent upon utilization of all types of automated manufacturing. The more extensive use of CAD/CAM or FMS, for example, the greater the need for communication networks. The capability for various portions of these systems to interact is still in need of development. Turnkey houses, users and primary system manufacturers are providing communication networks. Some political efforts have been made to establish standards which permit equipment from competing manufacturers to be utilized in the same system.

Flexible Manufacturing Systems

The machine tool and metalworking equipment industry is historically conservative. Companies react slowly to new developments. That attitude is changing due in part to technical developments and in part to economic driving forces. As part of the economics, customers no longer limit their choices to domestic producers. For example, ten years ago imported machine tools (including those built abroad by subsidiaries of U.S. companies) represented less than 10 percent of the U.S. market. Today that share is twice as large. U.S. import markets have grown in size and have changed in composition as well during the decade. Ten years ago imports were primarily standard machine tools manufactured in Western Europe (West Germany predominantly). Today Japan is the leading source and Japanese equipment is dominated by technologically advanced computer controlled machining centers.

Traditional customers for machine tool and metalworking equipment such as automotive, aerospace, heavy equipment and machinery and household appliances are suffering from low capacity utilization, high interest rates and increased foreign competition.

In an effort to respond to these pressures, metalworking equipment producers are increasingly buying and sharing new technologies with smaller, newer companies. The U.S. still remains the leader in technology development but not in application. The interactions among companies is an effort to recapture that application lead.

Total world market for Flexible Manufacturing Systems in 1982 was $4 billion. Utilization of such systems is expected to grow at 25 percent per year to a total of $37 billion in 1992. The partition of the market among the three major geographic portions of the industrialized world is given in Table A-3. Major vendors are given in Table A-4.

CAD/CAM Equipment

Sales of CAD/CAM equipment are dominated by U.S. vendors. Of the various types of vendors, turnkey systems manufacturers controlled almost 85 percent of the 1982 market. A turnkey CAD/CAM system includes four distinct parts:

- An integrated set of hardware such as the work stations, system processor, output stations interfaces and interconnecting cables
- Software
- Vendor services for installation, maintenance, and elimination of problems (debugging) for both hardware and software
- Education and engineering assistance such as training for management and operations and help with applications and special purpose programming.

Mainframe computer manufacturers and machining systems manufacturers controlled the remaining 15 percent. The major U.S. manufacturers and their 1982 market share is given in Table A-5. Japanese CAD/CAM manufacturers are given in Table A-6. Their equipment is used by electronics manufacturers in Japan.

This equipment was sold to users throughout the world. World sales of CAD/CAM equipment are shown in Table A-7. Battelle estimates that total sales for CAD/CAM will grow 25 percent annually through 1987 and 35 percent annually through 1992. Distribution of those projected sales by geographic sector is given in Table A-8. Sales of turnkey and mainframe market segments are shown in Table A-9.

It is interesting to note that according to a recent survey approximately half of all CAD/CAM users today have systems that are less than two years old. The growth of CAD/CAM turnkey systems has consistently exceeded market analysts' estimates. In the last four years, turnkey systems have experienced a 55 percent compound annual growth. The primary market for these systems was "Fortune 100 type" companies. This was due primarily to high initial costs and lack of experience based on anticipated benefits by smaller companies. Now that user benefits are being documented and the costs of CAD/CAM systems are decreasing, it is anticipated that the second market will be companies whose annual sales are $10 to $100 million.

CAD/CAM equipment can be divided in terms of the complexity of the system between sophisticated systems vs. limited function systems. Limited function systems are those which sell for under $100,000. They are a new entry into the marketplace and result from decreasing costs per computer operation, decreasing storage costs, decreasing software system costs, and increased experience by vendors with application needs. Current and future sales for these two types of systems in given in Table A-11.

Mechanical industry applications dominate in 1982 and will continue to do so in terms of dollar volume for the rest of the decade. Most of this market is U.S. based. Mechanical industry applications are in the traditional major metalworking industries such as automotive, machinery and aerospace. Distribution of CAD/CAM systems among various user types is shown in Table A-10. There is a pent-up demand for new equipment in these markets which has not been released due to a combination of factors such as:

- Loss of sales due to economic recession
- Competition from foreign (mainly Japanese) manufacturers
- Unwillingness to commit large amounts of funds for long-term returns
- Traditionally conservative attitudes toward new technologies/manufacturing techniques.

These applications will continue to need specialized CAD/CAM equipment and extensive peripheral equipment. These industries will benefit most from development in FMS.

CAD/CAM applications in other industry sectors (electronics, architectural engineering and construction applications, mapping and others) will experience more rapid growth rates than the mechanical sector.

Applications will benefit greatly from lower cost, dedicated systems. All of these application areas are well suited to dedicated design/manufacturing systems because the design is complex and time consuming. For instance, companies in electronics use CAD/CAM in the design and production of integrated circuits and printed circuits. In the electronics area, there is a growing trend to custom integrated circuits. Although the same function can be provided by gate arrays, CAD/CAM can be used just as effectively to produce both custom and semicustom designs. In fact, in manufacturing complex integrated and printed circuit systems, CAD/CAM is the only way to design and track the intricate circuitry. Architecture and engineering applications include plant design, residential and non-residential construction and energy use efficiency. One of the major factors restraining growth in these areas has been cost of the CAD/CAM system. As low cost CAD/CAM systems become available, application in these sectors will increase.

Use of CAD/CAM in mapping has the potential for good growth in the next decade. CAD/CAM equipment and software will increase productivity and reduce costs. However, this market area is extremely cost driven. Expenditures by government and energy companies for energy exploration, land conservation and management have been reduced in recent years. Thus, growth of CAD/CAM usage in this area will be slow. Table A-11 provides growth projections for low cost vs. sophisticated systems. Table A-12 shows users of low cost systems. Both small and large companies have an interest in low cost systems; large companies tend toward more sophisticated CAD/CAM equipment. Large company interest in large systems is encouraged by their desire to capitalize on more efficient use of higher priced systems

Robotics

The robotics market is a rapidly developing market whose size is a function of how robots are defined. For the purpose of this report, it will not include mechanical transfer devices known as pick and place robots. Such devices are included by the Japanese as robotics, but are not considered robots in the U.S. or Europe. Robot use is expected to grow worldwide for the next decade as seen in Table A-13. Table A-14 shows geographic distribution of robot markets.

The number of robot manufacturers has grown rapidly in the last few years. The approximate numbers of manufacturers by geographic region is:

• U.S.:	60
• Japan:	75
• Europe:	40

A list of major manufacturers is given in Table A-15.

Currently robots are being used primarily in the automotive, metalworking machinery, glass, rubber and electronics industries. Principal applications have included welding, materials handling, machine loading, spraying, inspection and assembly. Relative rates of growth for these applications is given in Table A-16. Assembly robots require the greatest level of sophistication in terms of precision, sensor and feedback control. Based on the variety of applications and opportunities in which such robots could be used, application of robots in assembly is expected to grow faster in the latter half of the decade than in the other existing applications. As a result, assembly robots are receiving a great deal of attention by new producers. Also, R&D funds are being allocated to development of this type of robot.

Materials Handling Equipment

Materials handling equipment includes equipment and controls used for handling, storing, retrieving, and transporting materials. It includes such items as lift trucks, horizontal transportation, automated storage and retrieval systems (AS/AR) and automated identification systems.

Two trends are emerging in materials handling:

- Turnkey handling systems - companies are providing a variety of related handling products, controls and services rather than a specific product group
- Computerized/automated controls and equipment - traditional equipment is being integrated into systems by use of microprocessors/microcomputers.

Major materials handling companies are given in Table A-17.

Major uses of sophisticated materials handling equipment traditionally have been Fortune 1000 type companies. These large companies will remain the major user segments throughout the decade as they continue to incorporate sophisticated CAD/CAM and FMS equipment. The area of greatest potential for new technology is automated storage and retrieval systems (AS/RS). Increased use of automatic material handling systems is highly dependent upon economic factors. Purchase of materials handling equipment is determined by profits of manufacturing companies as well as interest rates since the equipment represents sizeable investments. Forecasts for the MHE markets are given in Table A-18.

Software

Technological advancements in the hardware of CAD/CAM have progressed more rapidly than software developments throughout the 1970's decade. In fact, technological developments and the concurrent improvements in price/performance relationships have been the driving forces for the CAD industry throughout the 1970's. Developments in software have progressed more slowly. Because of the labor intensity in developing software, productivity has shown little improvement.

CAD/CAM software can be classified into three groups:

- Operating System Software
- Basic Graphics and Special Applications Software
- Implementation (Utility) Software

Most software is currently provided by the CAD/CAM turnkey vendors or developed by users. Very little is being developed by third party software suppliers. Examples of third party software suppliers are listed in Table A-19.

A great deal of effort and expense is being expended for software developments. A trend is developing for larger companies to license and link up with existing software developers. Also, there is a great deal of non-industrial support for software developments. In Europe and Japan, universities are funding software research and developments partly in the hope that such developments will enable them to realize significant rewards. Efforts are being directed toward

- Solids Modeling Systems
- Finite Element Analysis
- Group Technology
- Process Planning
- Test and Inspection Systems

In the U.S., several companies are adopting the Interactive Graphics Exchange Specification (IGES) recently adopted by ANSI. Inclusion of this program will allow equipment produced by different companies to send and receive data without forcing them to speak the same language.

Estimates of markets for software are given in Table A-20.

Networks

The current "performance standard" structure for computing and/or control systems is distributed processing with or without a central control processor. Local area networks (LANs) are required for this type of computing and/or control system. Examples of distributed systems are: intelligent CAD/CAM workstations tied to a central mainframe or minicomputer; several networked programmable controllers controlling various interrelated pieces of equipment on the shop floor; and Distributed Numerical Control.

Networks are of two fundamentally different types:

- Hierarchical
- Distributed

Hierarchical networks utilize a central controller to control all the data which flows to and from the various devices on the network. The central computer is usually a large mainframe computer. Such a system is totally dependent on the mainframe. Overloads can slow data processing. Mainframe failures shut down the entire system. Stations in distributed systems communicate directly with each other. In such a system each station must have an interface which can control the data flow to and from the system.

Local area networks are being developed by both factory automation users and computer houses. Vendors are listed in Table A-21.

The need for networks follows directly from the increasing use of "CAD/CAM" type systems.

TABLE A-3. WORLD CONSUMPTION OF FLEXIBLE MANUFACTURING SYSTEMS

Region	1982 Value, Billion U.S.$	%(2)	1992 Value, Billion U.S.$	%
Japan	2.0	50	14	45
Western Europe	1.2	30	6	20
U.S.	0.8	20	10	35
Total	4.0(1)	100	30(3)	100

(1) G.E. projection for 1982.

(2) Literature.

(3) ADL projects $100 billion.

TABLE A-4. MAJOR MANUFACTURERS OF FACTORY AUTOMATION SYSTEMS

U.S. Manufacturers

- Bendix (new entry)
- General Electric Company
- Westinghouse Electric Company
- International Business Machines Corp.
- Cincinnati Milacron Inc.
- Lamb Technicon Corp.
- Cross and Treaker Corp.
- Giddings & Lewis

Japanese Manufacturers

- Toshiba
- Mitsubishi Electric
- Fujitsu
- Nippon Electric
- Matsushita Electric

TABLE A-5. MAJOR U.S. VENDORS OF CAD/CAM TURNKEY SYSTEMS(1)

Company	Market Share, %
Computervision	28
IBM	20
Calma	12
Intergraph	12
Applicon	8
Auto Tool	4
McDonnell Douglas	4
Other (Gertler Scientific, Hewlett Packard, Perkin-Elmer, et al.)	12
Total	100

Source: Battelle.
(1) Excluding captive production.

TABLE A-6. MAJOR JAPANESE CAD/CAM SYSTEMS SUPPLIERS(1)

Hitachi
Sharp
Fujitou
NEC
Oki
Seiko
Mitsubishi

(1) Most Japanese CAD/CAM is used for electronics design, i.e., IC and PC layout. American imports dominate sales.

TABLE A-7. WORLDWIDE CAD/CAM SALES

Year	Value, Million U.S.$
1982	1,300
1987	3,700
1992	15,000

Source: Battelle.

TABLE A-8. CAD/CAM CONSUMPTION AND PRODUCTION BY GEOGRAPHIC REGION, 1982

	% Total	
Region	Consumption	Production
Europe	8	2
Japan	17	3
United States	75	95
	100	100

Source: Battelle.

TABLE A-9. WORLD MARKETS FOR CAD/CAM TURNKEY VS. MAINFRAME SYSTEMS (10^6 $)

System Type	1982	1987	1992
Turnkey	$ 1,100	$ 3,200	$13,200
Mainframe	200	500	1,800
Total	$ 1,300	$ 3,700	$15,000

Source: Battelle.

TABLE A-10. MARKET SHARES OF TURNKEY APPLICATION

Industry	% of Total, 1982
Mechanical Application	40
Electronics	30
Printed Circuit Board	
Integrated Circuits	
Architectural, Engineering, and Construction	15
Mapping	10
Other	5
Total	100

Source: Battelle.

TABLE A-11. TURNKEY CAD/CAM APPLICATIONS BY COMPLEXITY OF EQUIPMENT

Type System	Millions $U.S. 1982	 1987	 1992
Low Cost	$ 130	$ 600	$ 2,200
Sophisticated	970	2,600	11,000
Total	$1,100	$3,200	$13,200

Source: Battelle.

TABLE A-12. LOW-COST CAD/CAM APPLICATION BY INDUSTRY

	% of Application(1) 1982	 1986
Mechanical Application	14	25
Electronics		
P.C.	50	24
I.C.	2	17
AEC	34	34
Total	100	100

(1) Computerworld, June 28, 1982.

Source: Battelle

TABLE A-13. TOTAL WORLDWIDE ROBOT CONSUMPTION

Year	Total Sales, million U.S.$
1982	660
1987	1,800
1992	4,600

Source: Battelle.

TABLE A-14. GEOGRAPHIC DISTRIBUTION OF ROBOT CONSUMPTION

Region	% of Consumption		
	1982	1987	1992
United States	26	29	42
Japan	66	61	47
Europe	8	10	11
Total	100	100	100

Source: Battelle.

TABLE A-15. MAJOR ROBOTICS MANUFACTURERS

U.S.	Europe	Japan
Atlas-Copco	Acma Cribier	Dainichi-Kiko
Bendix	Agea	Fumitsu Fanus
Cincinnati-Milacron	Bisfer	Hitachi
IBM	Bosch	Kawasaki
NEC	Comau	Kuka
Prab	DEA	Mitsubishi Electric
Unimation	Jobs	Hochi Fujikoshi
Westinghouse	Jungheinrich	Osaka
	Olivetti	Sankyo
	Trallfa	Scemi
	V.W.	Yaskawa

TABLE A-16. ANTICIPATED DEVELOPMENTS BY APPLICATION AREA

Activity	1982-1987	1987-1992
Welding	Increased growth	Slower growth
Parts Assembly and Materials Handling	Slow growth	Increased growth
Machine Loading	Increased growth	
Spraying	Increased growth	Slower growth
Complex Inspection	Slow growth	Increased growth

Source: Battelle.

TABLE A-17. MATERIALS HANDLING EQUIPMENT VENDORS

Litton Industries

Eaton & Clark Equipment

S.I. Handling Systems

Buckhorn, Inc.

A. T. Kearney

FMC

Fanus

TABLE A-18. MATERIALS HANDLING EQUIPMENT SALES

Year	Sales, billion U.S.$	% Automated
1982	4	25
1987	7	35
1992	21	50

Source: Battelle.

TABLE A-19. SOFTWARE VENDORS OTHER THAN CAD/CAM VENDORS

U.S.

- Lockheed California Company
- Integrated Software Systems
- Manufacturing and Consulting Services
- Mechanical Dynamics
- Softech
- Structural Dynamics Research Corporation
- University Computing Company

Japan

- University of Tokyo
- Mitsui
- Fujitsu

Europe

- Compeda (England)
- Joseph Lucas Ltd. (England)
- Pafec Ltd. (England)
- Production Engineering Rsch. Assr. (England)
- Shape Data Ltd. (England)
- TNO (Netherlands)

TABLE A-20. SOFTWARE MARKETS

	Sales, million U.S.$	
Year	Manufacturing	CAD/CAM
1982	150	140
1987	500	800
1992	3,300	4,500

Source: Battelle.

TABLE A-21. NETWORKS

Vendors

- Industrial Solid State Controls (COPNET)
- Intersil (General Electric) (GEnet)
- Digital Equipment Corporation (DECNET)
- Texas Instruments (TIWAY I)
- Allen-Bradley
- Factory Automation Division of Gould, Inc.

Companies which have developed own networks:

- Grumman Aerospace Corporation (GEMS)
- Boeing Commercial Airplane Company (CIIN) (CAD/CAM Integrated Information Network)
- Sikorsky Aircraft (division of United Technology Corporation) (CAIDS) (Computer-Aided Interactive Design System)

APPENDIX B

CURRENT AND PLANNED APPLICATIONS OF CAD/CAM TECHNOLOGY IN ALBERTA

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CURRENT AND PLANNED APPLICATIONS OF CAD/CAM TECHNOLOGY IN ALBERTA

INTRODUCTION

Forty key industry representatives were interviewed to collect the following information on the state of CAD/CAM technology use in Alberta. The results of these interviews are itemized in this Appendix.

This Appendix contains information on the history and present Alberta situation, future plans and opportunities of companies, education, infrastructure, and a list of companies interviewed.

HISTORY AND PRESENT SITUATION

History

CAD has had very few years in the Alberta marketplace with NC equipment being about 10 years old in Alberta and CNC only four years. CAD engineering and design stations have also only been used a few years in the province. Other technologies such as robotic equipment have yet to be introduced in Alberta along with FMS (Flexible Manufacturing Systems) for high productivity on short runs in small and medium sized companies. These technologies have received great acceptance in other countries and generally have given them a distinct temporary competitive edge.

The high technology countries have been more stable during the recession of 1982-1983 while the natural resource countries have been hurting. But even in both of these situations most countries have an emphasis on productivity improvement. Canada has had no increase in productivity since 1973, according to the chief economist for the Royal Bank of Canada, and this could be considered quite a loss compared to the advancements made by some other countries. In the international marketplace, this places us at quite a disadvantage. We are not able to compete in many export product areas let alone at home where it is even difficult to maintain domestic market share while facing cheaper high quality imports. With high technology automation these foreign competitors have reduced their costs of manufacturing significantly and while this brings their prices lower, they still maintain healthy profit margins.

Productivity improvement is now becoming the accepted direction in Canada and many companies have taken steps to evaluate and investigate new systems. Many acknowledge that the emphasis must be on higher quality at lower prices.

We have many strengths on which we can now grow natural resources, healthy environment, equity capital and much engineering expertise. Successful companies tend to attract others and even now, companies such as Bell Northern Research and Hewlett-Packard are making large commitments to substantial expansions in Alberta.

In the past, the straight exploiting of our natural resources has given us a quick bankroll but now only the development of related spin off industries and diversification can help achieve provincial economic stability. We can build now on our existing strengths, experiences and expertise.

The uncertainty of the present recessionary environment is stalling most companies from further expenditures on improvements. But there are already a number who have experienced a sharp increase in orders in the early part of 1983 and with this encouragement, they are laying plans for a resumption of growth and studying productivity improvements using high technology.

Only a very few companies have had some poor to mediocre experiences with CAD and this can be attributed to poor advice and improper introduction of the systems.

There are no CAD/CAM consultants available in the province. Most companies have used only the help of vendors.

CAD/CAM, NC and Robotic Equipment in Use

There are a total of approximately 60 CAD systems in the Province with about 300 work stations. This does not include host type systems which use third party software.

The distribution of CAD vendors is as follows:

Vendor	Systems	Workstations
Intergraph	23	160
Autotrol	16	66
Hewlett-Packard	5	5
Computervision	4	26
Sigma	2	7
Omnitech	2	2
System House	2	25
Gerber	1	1
Orchatec	1	1
Other	4	7
	60	300

Applications are mostly Architectural, Mechanical, Mapping and Engineering. Other applications include chip design and circuit board design.

Application areas are estimated to be as follows:

Architectural	20%
Mechanical	12%
Construction and Engineering	20%
Mapping	25%
Electrical	8%
Electronics	5%
Education	10%

Some of the food and beverage industry use hard automation for packaging, counting, material handling and processing of goods.

There are about 65 NC and CNC machines in the province. Gross Machinery has delivered over half of these machines (Japanese machines).

There are two manipulators in the province used in the oil industry. These units have some resemblence to robots, but technically they are not defined as robots.

A large telecommunications manufacturing company in Calgary has programmable robotic insertion units for automated assembly of printed circuit boards.

Maintenance and service of CAD and NC equipment is provided in Alberta by:

- Computervision
- Autotrol
- Intergraph
- Gross Machinery
- CAE Morse

The users of this technology in Alberta are not reducing staff as much as their competitors.

Other Technologies in Use

MRP (Material Requirements Planning) software is being used by most manufacturers of over $10 million in revenues. This software handles customer orders, production control, inventory and purchasing functions.

Process Control is used in the Industry by large companies, but not as widely as it could be. A great deal of application expertise does exist in the province, but most vendors are from the U.S. and the largest vendors are:

- Sentrol (Alberta company)
- Honeywell
- Johnson Controls
- Foxboro
- IBM

Awareness and Propensity to Change

Most companies of medium size are aware of CAD/CAM on a very general sense. But because of the economic slowdown CAD/CAM is not being evaluated immediately by the majority of companies.

Most companies do not feel the urgency to automate. They feel Canada must be more productive but that their company is in fairly good shape.

Almost all industries interviewed mentioned that the push for technology came from middle management. Senior management is usually very cautious and conservative in new technologies or plant changes. No industries had a specific productivity team or analyst for the company. Most companies used internal staff for investigating productivity problems.

Alberta companies in the past five years have been very busy profitting from a good economic climate. During this time they have not bothered much with technological improvements in their operations.

Most companies using CAD had slow start-ups, lengthy learning periods, and only after a year, were there any productivity increases. As their systems were being used more and more, new benefits were realized such as ease of design change and the flexibility of common data bases. Each of these companies still expects greater productivity in the future, even though start-up has been slow.

FUTURE PLANS AND OPPORTUNITIES

Present Plans of Companies

The following points are commitments and plans expressed by companies.

While the larger companies are planning and strengthening their productivity, medium and smaller companies are slow to begin changes in operations.

One engineering company has plans to design and implement a computer aided engineering system for Civil Engineering. A Civil data base would have standards, design rules, tables, design programs, test programs, drafting output, net list generation, etc. This would be a CAE-CAD product developed in Alberta.

A mapping data base and applications software on CAD is being pursued by two companies and over 10 companies are actively using these new software tools. Because Canada has provincial or federal control over maps, utilities, energy, etc., (U.S. uses smaller, privately owned systems and municipalities have not seen this opportunity yet) we are leaders in some mapping applications. New data bases would include topo maps, land ownership, cultural details, water, contours, resources, utilities, etc.

At least three design companies plan to deliver a building or plant data base with each building or factory design. From this, building maintenance, renovations and operations are much easier and more economical. This could develop into a future service product.

One manufacturer of electronics and mechanical assemblies is completely committed to CAD/CAM throughout their entire operation. Otherwise very few companies had a plan to incorporate the new technologies in the forseeable future.

Only a few metal fab companies out of about 1000 have definite plans to tie together tools (CAD) with production tools (CAM). Product design, material handling, direct numerical control (DNC) machines and robotics will all link to one computer system in the future.

One Alberta manufacturer is taking advantage of skyrocketing transportation costs by expanding his local market penetration with his ability to undercut imports by producing locally. This now enables him to consider new automation ideas because of higher volume.

A large bottling operation felt that plant automation would be a couple of years away while a major food processor planned on their entire operation going to solid state process control in the near future.

An Alberta consulting center is currently involved with local companies in the following projects:

- A major furniture manufacturer is in the first stages of implementing robotics into their painting system.
- A large heat exchange manufacturer is studying the introduction of a robot into its welding system.
- Three medium sized Alberta manufacturing companies have planning underway for a joint major CAD/CAM study.
- A few companies - metal fab, oilfield equipment and engineering firms are having CAD feasibility studies performed.
- A very large sophisticated CAD/CAM system has been installed at the University of Alberta and will be available for use by local companies. Awareness courses and use by industry on this equipment are part of plans.

Opportunities Mentioned at Interviews

The following potential opportunities are only ideas expressed at company interviews and were not part of the company's plans. Also, these ideas are not necessarily the recommendations or opinions of the authors. Major points made are the following:

(1) Agriculture was regarded highly for future development by most interviewed executives.
  - satellite sensing
  - irrigation extension and management
  - soil and crop management
  - herd management
  - semen and embroyo exporting
  - workstations or timeshare terminals for farmers
  - robotic tractors
  - feed manufacturing
  - meat products developed in large volume for far east export
  - crop yield R & D
  - environmental sensors

(2) Opportunities in other industries were as follows:
  - the cultivation and effective use of Aspen
  - satellite broadcasting and space technology
  - lasers and fiber optics
  - telecommunications

(3) The existing oil industry needs more automation in:
  - drilling
  - pipelines
  - exploration
  - production
  - process plants

(4) The oilfield equipment manufacturing and service industries should be encouraged to world market proportions. We have great expertise and some very good products. With more development we could expand this entire industry. By taking only a small piece of the world market it would expand our manufacturing base greatly.

(5) A network of mapping data bases between users and providers of data is needed.

(6) A network data for communications between all CAD systems (even different vendors) would be helpful.

(7) Apply electronic office and communications expertise to manufacturing management.

(8) Artificial intelligence will be very important in future human interface systems. This is a natural development to pursue in medical R & D.

(9) Any opportunities pursued by Alberta should be characterized as follows:

- world class
- exportable
- technology oriented
- sell applications not the hardware

(10) Low cost CAD/CAM systems should be developed for the multitude of small to medium sized companies in Alberta.

(11) Developing interests where the government has already injected substantial funding can be beneficial for the future. These areas are:

- Agriculture
- Natural Resources
- Medicine
- Environmental

(12) The development of a chemical manufacturing industry could be a great opportunity as an offshoot of the Medical Research programs in the province.

(13) Leather products manufacturing could be a natural offshoot of the cattle and hide industry. We now export hides and import shoes and other leather products.

(14) Alberta has developed much expertise in software and resource management. Software programs should be packaged for export all over the world. This would open up opportunities for much service and consulting work in other countries. Many third world countries will need our expertise in resource management.

(15) There are a large number of software experts in the province involved with geophysical applications, real time systems, oil industry engineering and applications, project management, process control and data processing. This large pool of professionals is a strong resource for a software industry.

(14) A large majority of executives interviewed mentioned that Alberta should stay out of "chip" and mainframe or computer manufacturing. Reasoning was that the competition is too heavy for us.

(17) Apply leading edge technology to new pilot plants for R & D in coal processing, heavy oils and nuclear fusion.

(18) Alberta has considerable expertise in education research and computer assisted instruction (CAI) tools. A large CAI program could benefit all industries and would enable Alberta to export CAI products, software and services. CAI is a form of a CAD workstation with its interactive graphics, human interfaces and data bases.

(19) Sensors is a key technology which can be applied to local resource markets and internationally. Expertise in the resource industry and at the U of A could provide Alberta with opportunities of capturing unique application areas using custom sensors. Some applications are sensing of chemicals, air pollutants, oil viscosity, hydrogen sulphide, and special pressure and temperature sensing.

(20) Because of Alberta's and the north's vastness, applications of electronics to our environment should be encouraged. Because of our environment, we have a natural testing ground for bad static conditions, and extreme temperature and industrial conditions. Applications here are:

- remote data collection and control
- remote surveillance and alarm systems
- distributed, remote communications systems

(21) As our fuel is cheaper in Alberta and since we are close to many raw materials, we should encourage industries which are high fuel and natural resource consumers.

General Comments

A general Alberta "Productivity and Innovation Push" is required. It is an international concern, and it should be encouraged and supported for all industry sectors.

Most of the executives interviewed had real problems defining good application areas for CAD/CAM. They were interested in it because it was an upcoming technology but not because it was a productivity improvement tool. There were some suspicions as to the complexity, difficulty and expense in implementing CAD/CAM programs in view of the present recession.

Some manufacturing companies have cut back their staff so extensively that they are far too thin to think of present operational innovations; e.g., 250 staff down to only a couple of dozen.

It was apparent almost all people interviewed could not even think of one or two years away, let alone 10. Only a few companies had any long term objectives and strategies.

APPENDIX C

POTENTIAL OPPORTUNITIES(1)(2) FOR ALBERTA IN CAD/CAM RELATED TECHNOLOGIES CATEGORIZED BY VARIOUS INDUSTRY ANALOGIES TO CAD/CAM TECHNOLOGY

(1) These opportunities are not separated in this appendix into R&D, Utilization/Application and New Product possibilities. They were separated into those categories for screening purposes.

(2) Additional items were added to this list in the Manufacture categories. In general these were advanced technologies not applicable to Alberta in the near term.

ARCHITECTURE

CAD	CAM	Robotics	AMH	Group Technology	CNC/DNC	MRP & MP & CS
Civil Engineering Data Base (Product R&D)	Paperless Operations			Modularity of Building Parts & Concepts		Financial & Economic Modeling
Low Cost CAD Workstation (S/W Product)						Automate Bill of Materials for Building
Building & Landscape Graphics for Concept Design						Management Software for Architecture Methods & Procedures
Building Energy Management Design						Project Management Packages
Integration of Architecture & Construction Design, Planning Software and Costing						

Computer & Software	Graphics	Data Bases	Communications	Sensors & Control	Remote Sensing	Others
Engineering Design & Optimization Tools	Software for Sketches Concept Drawings & Marketing Materials	Building Service & Maintenance Data Base for Each Building With Graphics				
		Building Management, Scheduling & Energy, Conservation on Line for the Building				

CONSTRUCTION

CAD	CAM	Robotics	AMH	Group Technology	CNC/DNC	MRP & MP & CS
Building Maintenance & Management on CAD	Plant Control for Materials Building System	Manipulators - for Construction Industry	Smart Cranes Know Building Shape, Material Lifted, Cable Stress, Structural Stress (Prevents Accidents)			Project Management
Arctic Building Design System	Oil Derivative Building Products	Arctic Assembly				Resource Management (Labor, Materials, Subcontractors & Equipment)
Plant Design Package	Prefab House Design, Cutting & Assembly	Pipeline Assembly				Graphic CP & PERT
Turnkey Design Packages	Automatic Glass Cutting, Wastage Minimized & Handling	Small Tools				Financial Control
Net List Generation (Material Lists)	Solar Energy Products	Concrete Finishing For Floors				
		Robotic Vacuum Cleaner & Floor Cleaner				

Computer & Software	Graphics	Data Bases	Communications	Sensors & Control	Remote Sensing	Others
Integrate CAE & CAD	Paperless Operations With Remote Graphics on Site	Building Codes & Standards on System	Network Status of Construction to Control Computer for Up-to-Date Project Status	Energy Management		CCD, Optic, Laser Scanners to Read Old Drawings Into Digital Data Base
	Visual Progress Tracking Actual and Expected Work Completed for Control and Quality Checking (Building, Highways, Pipelines)	Steel Detailing Designs in Data Base		Security Systems		
				Cement Plant Process Control Systems		

AGRICULTURE

CAD

Meat Cutting

Large Farm Layout

Display - Soil Analysis & Crop Yield on All Fields

CAM

Up North Greenhouse

Soya Production

Automated Combine

Manufacture By-Products
- Cereals
- Prepared Meats
- Oils
- Dairy Produce
- Beverages
- Hides (Tanning)
- Shoes
- Wool & Clothes
- Leather Products
- Furs

Manufacture Farm Equipment
- Implements
- Tractors
- Farm Electronics

Robotics

Bone Extraction

Meat Cutting Tractor

Sheep Shearing

Cattle Handling For Branding

Land Breaking and Clearing Machine

Automatic Fencing System for Posts and Wire

AMH

Vegetable Pickers

Gantry System for All Field Work

Container Systems For Grain

Egg System:
- Inspect & Package

Grain Handling Alternatives (Pipeline Derigable)

Meat Packaging & Labeling

Group Technology

CNC/DNC

MRP & MP & CS

House:
- Financial Records
- Livestock Records
- Agribusiness Marketing Analysis
- Forecasting

Breeding History of Cattle

Automated Beef Slaughtering

Automated Tannery

Grain Transportation System Management

Provincial & Federal Crop Management S/W

Computer & Software

Genetics, Correlation of Breeding Data

Feed Analysis

Graphics

Data Bases

Pelletizing of Products

Container & Label Machines

Aseptic Packaging

Concentrated Foods

Chemical Additives

Communications

Remote Telemetry to Home

Farm Networks

Information System to Farmer

Education Systems

Time Share Systems to a Large Host

Remote Livestock Monitoring

50 Farming Data Bases Exist in Alberta - Get to Farmers

Sensors & Control

Vegetable Maturity & Damage Detection

Spoilage Sensing

Weight Monitors in Trucks and Hoppers (Board Cells)

Loss Monitors for Combines

Energy Management (Slippage, Draw Bar, Revs, Heat & Exhaust)

Automated Tractor:
- Collision Sensing
- Auto Steering
- Moisture Sensor
- Implement Control

Remote Sensing

Remote Sensing:
- Disease
- Locusts
- Crop Production
- Demographics
- Future Expansion
- Crop Maturity

Weather Prediction

Others

AGRICULTURE (CONTINUED)

Computer & Software	Graphics	Data Bases	Communications	Sensors & Control		Remote Sensing	Others
				Security	Seeding Monitors		
				Fencing (Invisible)	Spray Monitors		
				Energy Management in Buildings	Weed Killing Using Microwave or High Voltage		
				Monitor Heat Lamps for Pig Farms	Auger Full Detector to Stop Plugging & Broken Equipment		
				Power Load Shedding (Energy)			
				Water Flow Measure & Control	Soil Analysis		
				Egg System: - Sense & Control	Grain Contact & Mining Systems		
				Depth Control: - Moisture - Soil Chemistry	Grain Dryers Using Controllers & Microwave		
				Fertilizer Spreader			
				Moisture Sensors: - Grain - Field - Ground - For Irrigation			
				Milk Cows: - Feed Mix & Cow Transpnder - History & Cow - Disease Detect - Heat & Pregnancy Detection - Calving Detectors			

NATURAL RESOURCES

CAD	CAM	Robotics	AMH	Group Technology	CNC/DNC	MRP & MP & CS
			Slurry Pipe Line Solids & Liquid Export	Rig & Plant Manufacture Companies	Portable Pipeline Units for Machining & Cutting	Resource Management: - Inventory - Analysis - Data Capture - Forecasting - Market Forecast - Sell to 3rd World
			Other Handling Alternatives for Oil (Derigables)	Up North Vehicles		Northern Development Methods
						Resource Management of: - Oils - Gas - Heay Oils - Water
						Plant Simulation & Modeling

Computer & Software	Graphics	Data Bases	Communications	Sensors & Control		Remote Sensing	Others
Process Control - Algorithms	Geophysical - Imaging Processing - Graphics	Mapping - Data Bases - Natural Resources - Topo Graphics	Remote Data Collection	SCADA Especially for Up North	Specialty Chemicals - Sense, Analyze	Exploration Mapping	
Dynamic Analysis & Modeling		Seismic Data Base	Natural Resources Network for SCADA	Sensors: - H2S, Viscosity - Water & Chemical Analysis	New Feedback, Predicting, Analytical, Etc.	Aerial Photography	
Real Time Analysis Display of Drill Bits Wear				Wear on Drill Bits	Process Control Algorithms	Woodlands Sensing for Fires, Roads, Erosion, Replanting, Etc.	
Geophysical: - 3D - Interpretation - Imaging Processors				Security Systems	Micros in Gas Furnaces in Houses	Satellite Sensing for Forest Fires & Disease	
Environmental Models				Seismic Data Collection	Plant & Process Optimization		
Payback & ROI Models				Gamma Spectrometry	Rig Crown Saver to Monitor Operation & Safety		
Drill Site Exploration				Wire Line Logging			
Time of Day-Remote Meter Reading				Well Blowout Detection	Automate Data Capture for Seismic Records (Scanners)		
Drilling Simulators				Underground Pressure Sensing			
Well Log Data Analysis				Auto Pipeline Sense & Control for Leak			
Reservoir Modeling							

MINING

CAD	CAM	Robotics	AMH	Group Technology	CNC/DNC	MRP & MP & CS
Design of Explosive Size, Area & Placement Borrow Pit Design Mapping For Exploration Plot Product Quality and Quantity on Maps	Manufacture Secondary Products - Coke - Chemicals - Pitch - Drugs - Plastics - Solvents	Maintenance Equipment Cleaning Robots Electronics Manufacturing Mining Robots for Excavation, Material Handling, Setting Explosives, Mine Testing, Installing Supports, & Safety Operations	Guided Vehicles for Coal Transport Conveyor Systems Other Handling System Developments		Coal Process Units Computer Controlled	Resource Management for Exploration, Excavation, Borrow Pits, Mining, Transport Process and Market Project Management of Operations

Computer & Software	Graphics	Data Bases	Communications	Sensors & Control	Remote Sensing	Others
Coal Field Analysis Coal Quality Analysis Economic Feasibility Software	Subsurface Material Analysis & Displays Mining Development Graphics Showing Layouts of Tunnels	Mapping Data Base Field Analysis	Mining Networks	Analysis of Mining Material While Mining - Ash, Water, Etc. Coordinate Measurement (QA) Tool Wear Sensing Energy Management Systems Gas Sensors - Methane, Dust, Fire, CO_2, Sulphur	Sub-Surface & Surface Image Processing for Exploration	

FORESTRY

CAD	CAM	Robotics	AMH	Group Technology	CNC/DNC	MRP & MP & CS
Layout Graphics of Roads, Lumber Type, Timbering Patterns for Hauling Optimization & Economic Analysis Design of Pre-casting Forms & Wood Construction Materials	Manufacture by Products: - Lumber - Furniture - Plywood - Newsprint - Cardboard - Pulp - Books - Newspapers - Office Supplies	Log Handling Tree Cutting Tree Stripping	Finished Wood Handling and Packaging Saw Mill Material Handlers		Develop & Apply CNC Wood Working Machines	Resource Management & Financial & Market Management Project Management of Saw Mills and Factories (Schedules, Costs, Etc.)

Computer & Software	Graphics	Data Bases	Communications	Sensors & Control	Remote Sensing	Others
Optimizing Cutting of Logs		Forestry Reserves Defining Species, Size, Density, Accessability, Quotas Graphic Display of Above Resource Data Merging of All Demographic, Resource, Topographic, Social, Economic, Political Data Bases With Graphics		Forest Management: - Fire - Communication Paper Quality and Thickness Pulp Quality Disease Sensors for Logs Grain Sensing for Logs Detect Tree Types & Quality for Saw Mills	Detecting: - Tree Maturity - Fire - Disease - Species Distribution - Tree Densities - Accessibility	

MANUFACTURING

CAD

- Configuration Control Software
- CAD/CAM for Industry Metal Products
- CAD-Low Cost Turnkey (Metal Fab)
- Mold Design
- Gear Design

CAM

- Laser Welding
- Laser Cutting
- Laser Marking
- Motors, Pumps, Valves
- Explosion Proof, Safety Valves & Products
- CAD/CAM for Industry Metal Products
- Handling Equipment
- Food & Beverage Handling Systems
- Disposable Packaging
- Plastic/Glass/Cans
- Plastic Molds - CAD/CAM
- Pigs (Inside Pipeline Robots)
- Plastic Products
- Automated Metal Fab
- Pipelines for Solids
- Beef Substitutes
- Dehydrated & Freeze Dried
- Food Mixers
- Standard Packages & Products (Pellets)
- Continuous Noodle Making
- Flour Milling
- Baking & Cake Making
- Automated Restaurants
- Largest Import Food Products
- Largest Usage Food
- Automated Greenhouse
- Automated Metal Fab Factory
- Intelligent Conveyors and Handling Systems
- Paperless Operations
- Gear Manufacturing
- Semi-Automated Welding Jigs
- Export of the Food Produce Which has Most Value Added From Our Raw Materials
  - Vegetables
  - Water
  - Petrochemical
  - Shoes
  - Food Oils
  - Lumber Products
  - Newsprint
  - Furniture
- Develop Small Automated Food Processing Factories for Alberta. (Fish Filleting, Freezing, Packaging; Vegetables, Meats, Etc.)

Robotics

- Inspection Robots

AMH

- Beam Line Technology for Steel Beams
- Automatic Pelleting Systems
- Conveyor Systems
- Automated Warehouse
- Bar Codes Inventory

Group Technology

CNC/DNC

MRP & MP & CS

- Paperless Factory
- Factory Management

MANUFACTURING (CONTINUED)

CAD	CAM	Robotics	AMH	Group Technology	CNC/DNC	MRP & MP & CS
	Material Recovery - Scrap Metals (Separation of Materials) - Plastics - Glass - Newsprint Small Automated Plastic Manufacturing Systems Small Automated Foundries Mold Makers, Material Handlers Automated Sach, Cabinet, Doors, Fabrication & Milling Plants					

Computer & Software	Graphics	Data Bases	Communications	Sensors & Control	Remote Sensing	Others
Manufacturing Process Models Developed for Industry			DNC Interface Links Post Processor Development for NC Machines	Voice Activated Systems for Dangerous Jobs QA Coordinate Measurement Systems		

SERVICES & UTILITY INDUSTRY

CAD

- DNA Regeneration Graphics
- Medical Image Processing
- Gene Prediction
- Portable Graphics Maps on Line in Planes and Trucks
- TV & Film Animations & Simulations
- Weather Prediction & Mapping
- Interactive Patient Care Systems
- Design Analysis of Audio Effects of Materials and Room Shapes

CAM

- Glass Products & Cutting
- Optimized Cutting
- Prescription Glass Cutting Automated
- Automatic Dry-Cleaning Plant
- Optimization of Service Tools-Saw Sharpening
- Robotics for Storage & Checking for Public Use
- Medical Lab Test, Analysis Documentation Systems

Robotics

- Intelligent Fork Lift for High Rises
- Guidance of Blind in Hospitals
- Lift Handicaps to & From Wheelchair
- Janitorial Robots
- Domestic Robots
- Smart Hospital Beds & Patient Carriers
- Self-Feed Systems for Handicapped
- Garbage Manipulator Units for Garbage Collectors

AMH

- Underground Conveyors

Group Technology

CNC/DNC

MRP & MP & CS

- Project Management (MPR)
- Northern Supply Centre
- Municipal Resource
- Utility Management

Computer & Software

- CAI - S/W
- CAI - Laser Discs
- Optic Discs
- Medical R&D - Signal Processing
- Medical R&D - Medical Diagnostics
- CAI - Handicap Education

Graphics

Data Bases

- Mapping:
  - Municipal
  - Cultural, Topo, Contours
- Data Base Machine Readable

Communications

- Office Retrofitting - Power Line Carrier
- Remote Sensing of Heart Attack Victims & Sickness
- Remote Graphics on Trucks for Drawing & Maps
- Satellite System Development & Applications & R&D

Sensors & Control

- Guidance of Blind to and From Wheelchair
- Sonar Sensing
- Environmental Pollution Monitor & Report
- Weather Control
- Building Maintenance Control

Remote Sensing

Others

SERVICES & UTILITY INDUSTRY (CONTINUED)

Computer & Software	Graphics	Data Bases	Communications	Sensors & Control	Remote Sensing	Others
Student Record Keeping			Digital Transmission Research	Tank Metal Inspection		
CAI - Course Ware			Doctor & Patient Training	Vitamin Analysis & Production Product		
Curriculum Management			Computer Modeling in Medicine - Body Movements	Pollution Monitor & Control		
Multimedia Education			Remote Meter Reading, Alarm Monitoring and Energy Load Control	CCD Scanners, Character Recognition & Drawing Scanners for Data Capture		
Remote Education				Automated Ordering to Retail & Supplier		
Devices to Rural Areas						
Index 2 Classification Schemes						
S/W Productivity Tools						
Subdivision Layout and Optimization						
User Friendly Portable CAD Systems						
Cross Correlation Software for Multiple Data Bases for Provincial Demographics						
Integrated Data Bases Between Vendors						
Social Economic Data Bases for Community and Province						
CAI for Management Entrepreneuring, Resource Management (Alberta's Strengths & Weaknesses) & General Awareness						

GENERAL - TECHNOLOGY INTENSIVE

CAD		CAM	Robotics	AMH	Group Technology	CNC/DNC	MRP & MP & CS
Civil Engineering Data Base	Mapping Software	Amusement Services	Vision & Touch for Robots	Manufacture Conveyor Systems			Total Business Management Software
3-D Solids for Stress, Temperature, Etc.	Remote Sensing to CAD Screen Software	Laser Cutting & Marking	Up North Robots	Coal & Heavy Oil Handlers to be Exported			
Low Cost Metal Fab System	Easy Lama Interface Developed		Pipeline Robots	Pneumatic Pipelines for Solids			
Low Cost PCB Design Board	Use for Medical Research						
DNC Interfacing to Cad							

Computer & Software		Graphics	Data Bases	Communications	Sensors & Control	Remote Sensing	Others	
S/W Development	Fusion Research for Nuclear Power			Telecom	Optics - Comm.		Test Equipment - Telecom	Equipment for Cancer Cure & Other Health Care (Herpes & Arthritis Cures)
Products: Mapping S/W	Orbiting Solar Collection & Beam Energy to Earth			Data Communications	Energy Conservation		New Processes - CAD/CAM for Research	Regeneration of Nerve Pathways
Subsidize Personal Computers & S/W to Companies	Biofeedback Brain Wave Linking to Computers and ESP			Cellular Mobile Radio Communications	Intensive Care Systems		Biogenetics - Biochips - Semen & Embryo Export - Solar Photovoltaics - Computer Architecture - Display Technology	Weather Control
User Friendly Software for Alberta's Application Strengths	Voice Synthesis & Recognition				Sensor Development Lab for Industry Applications		Develop New "Winder Metals", Structural Ceramics, Fiber Graphics, Polymers, Superconductors, Components	Artificial Intelligence Research & Applications
S/W Productivity Tools	Antigravity Machine						Develop Plastics that Conduct Electricity "Memory" Metals	New Credit Card & Payment System
Military Products	Longbase Line Arrays for a Large Radio Telescope Across Canada						Cloning of People, Plants and Animals	Videotext, ISDN
Education Software	Safety Systems Sensors Environmental Protection Analysis & Control Electronics							Electronic Home Security Systems
Medical Electronics								
Optimize Human Interfaces (Sense Eye Movement to Turn Pages on a Screen)								
Holography Using Lasers								
Health Care Electronics								

APPENDIX D

CRITERIA USED TO SELECT OPPORTUNITIES IN CAD/CAM FOR ALBERTA

CRITERIA USED TO SELECT OPPORTUNITIES IN CAD/CAM FOR ALBERTA

The objective of this screening methodology is to make simple low cost decisions first and more difficult, more costly decisions later in order to conserve both time and funds. The most difficult, time consuming, costly decisions are made last. In practice, the following steps were followed:

(1) Opportunities were sorted into three categories: R&D, applications, and products.

(2) Obvious duplications, nonsense, and unclearly stated propositions were eliminated.

(3) The remaining subjects were aggregated to lists of similar subjects. Unclear statements were corrected.

(4) The lists were submitted to a limited number of persons to apply the elimination criteria. Agreement with any one criterion eliminated that opportunity.

(5) The results were correlated and judgemental decisions made on which could be reinserted on the list. Reasons for reinsertion were lack of knowledge on the part eliminating the proposition, special knowledge on the part of one person desiring the opportunity, or possible other valid considerations by one or more persons doing the selection.

(6) The culled lists were submitted to a larger group of persons for scoring.

(7) The results are again correlated and a meeting held among scorers to discuss the results and bring to bear any special knowledge which would change the result.

(8) Some longer term or very special cases may warrant a different treatment. These will be noted.

(9) Prepare a final list of possibilities.

A major caveat in use of this methodology is that the methodology itself is not the end objective. The important aspect of the exercise is the thinking process necessary to arrive at a valid conclusion. Any information to improve the validity of the conclusion should be considered.

TABLE D-1. ELIMINATION[1] CRITERIA FOR SCREENING OPPORTUNITIES FOR CAD/CAM IN ALBERTA

Research and Development

- Downstream benefits are not apparent.
- Opportunity requires development of basic or fundamental knowledge to complete project.
- Resources required are not available in Alberta and are very costly to acquire.
- Impact of successful conclusion would not be large.

Application/Utilization

- Impact of identified application is not apparent in 1-5 year period or there is no apparent need for application in Alberta in 5-10 year future.
- Application requires significant R&D to be utilized (perhaps evaluate as R&D possibility)
- Human and material resources required for application not available or are costly to acquire
- Industry where application is utilized has poor growth potential

Products and Services

- Market for product or service is strictly domestic
- Rate of change of technology of product in world is so high as to preclude Alberta competing, i.e., rapid technological obsolescence is likely.
- Required parts and technology are not available in Alberta or are not readily acquired
- The product or service is not in an identified high growth area.

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(1) Any single criterion which is true will eliminate a potential opportunity from further consideration.

Source: Study Team.

TABLE D-2. CRITERIA FOR SCORING(1) CAD/CAM OPPORTUNITIES FOR ALBERTA

Research and Development

- Probability of success is high
- A successful result has a high probability of enhancing both domestic and export position of Alberta
- Project can be completed in a reasonable time, e.g., less than 2-3 years
- The identified benefits have a high benefit/cost ratio - e.g., greater than 100 to 1
- Successful conclusion has broad application in Alberta.

Application/Utilization

- Application will significantly improve productivity or cost position of Alberta products or services
- Application will significantly contribute to value added in Alberta
- Application will significantly broaden manufactured product base in Alberta
- Application will require significant upgrading of human skills in Alberta
- Application has potential for being used outside major metropolitan areas
- Industry for application has high future growth potential

Products and Services

- Product development and engineering only are required to bring product to market. A maximum of 1-2 years to production would be required.
- No other company or country has a preferred position in the marketplace. Alberta should aspire to at least $10 million sales annually.

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(1) All criteria are ranked for each opportunity. The highest cumulative scores indicate better opportunities.

Source: Study Team.

TABLE D-2. (CONTINUED)

- Alberta has the potential for developing a reasonably unique position (market niche), possibly top 1 to 3 suppliers for specific product
- Necessary infrastructure and supporting industry are present
- Alberta geographic location does not adversely affect marketing product. (Transportation costs are not important.)
- Continued government support is not required.

APPENDIX E

COMPLETE LIST OF OPPORTUNITIES FOR CAD/CAM TECHNOLOGIES

TABLE E-1. OPPORTUNITIES FOR R&D IN CAD/CAM IN ALBERTA

Agriculture

● Robotic Bone Extraction

● Robotic Meat Cutting

Robotic Sheep Shearing

Robotic Cattle Handling for Branding

Robotic Land Breaking and Clearing Machine

Automatic Fencing System for Posts and Wire

Automated Combine

● CAD Meat Cutting Design

Grain Handling Alternatives (Pipeline, Dirigible)

Automated Vegetable Pickers

Automated Gantry System for All Field Work

● Product Loss Monitors for Combines

● Energy Management (Slippage, Draw Bar, Engine RPM, Heat and Exhaust)

● Grain Milling Systems

● Grain Dryers Using Controllers and Microwave

Automated Tractor:
  - Collision Sensing
  - Auto Steering
● - Moisture Sensor
● - Implement Control

Milk Cows:
● - Feed Mix and Cow Transponder
  - Disease Detection
● - Heat and Pregnancy Detection
● - Calving Detectors

● Automated Beef Slaughtering

● Automated Tannery

● CAD Display - Soil Analysis and Crop Yield on All Fields

● Remote Livestock Monitoring

Vegetable Maturity and Damage Detection

Spoilage Sensing

● Planting Depth Control:
  - Moisture
  - Soil Chemistry

Weed Killing Using Microwave or High Voltage

Auger Full Detector to Stop Plugging and Broken Equipment

● Soil Analysis Software and Sensors

● - Opportunities which passed Go/No-Go screening.

TABLE E-1. (CONTINUED)

Architecture, Engineering, and Construction

● Civil Engineering Data Base

● Integration of Architecture and Construction Design, Planning Software and Costing

● Engineering Design and Optimization Tools

Arctic Building Design System

Arctic Assembly

Smart Cranes Know Building Shape, Material Lifted, Cable Stress, Structural Stress (Prevents Accidents)

Manipulators - for Construction Industry

● Pipeline Assembly

Robotic Vacuum Cleaner and Floor Cleaner

CCD, Optic, Laser

Forestry

Remote Sensing of:

   - Tree Maturity
● - Fire
   - Disease
   - Species Distribution
● - Tree Densities
● - Accessibility

Forest Management:

● - Fire
● - Communication

● Detect Tree Types and Quality for Sawmills

Robotic Log Handling

Robotic Tree Cutting

Robotic Tree Stripping

Disease Sensors for Logs

● Grain Sensing for Logs

Sensors and Software for Edging and Grading

● Paper Quality and Thickness Sensors

Pulp Quality Sensors

TABLE E-1. (CONTINUED)

High Technology

New Processes - CAD/CAM for Research

Biogenetics

  - Biochips
  - Semen and Embryo Export
  - Solar Photovoltaics
  - Computer Architecture
  - Display Technology

Develop New "Wonder Metals", Structural Ceramics, Fiber Graphics, Polymers, Superconductors, Components

Develop Plastics that Conduct Electricity, "Memory" Metals

Cloning of People, Plants, and Animals

Equipment for Cancer Cure and Other Health Care (Herpes and Arthritis Cures)

Regeneration of Nerve Pathways

Weather Control

Artificial Intelligence for R&D

- Safety Systems Sensors
- Environmental Protection
- Analysis and Control Electronics
- User Friendly Software for Alberta's Application Strengths
- Software Productivity Tools

Eye Movement Sensors to Turn Pages on a Screen

Holography Using Lasers

- Sensor Development Lab for Industry Applications

Vision and Touch for Robots

Up North Robots

- Pipeline Robots

3-D Solids for Stress, Temperature, Etc.

- Low-Cost Metal Fab System

Low-Cost PCB Design Board

DNC Interfacing to CAD

- Mapping Software
- Remote Sensing to CAD Screen Software
- Easy Lama Interface Developed

Fusion Research for Nuclear Power

Orbiting Solar Collection and Beam Energy to Earth

Biofeedback Brain Wave Linking to Computers and ESP

Voice Synthesis and Recognition

Antigravity Machine

TABLE E-1. (CONTINUED)

Mining

- Design of Explosive Size, Area and Placement
- Borrow Pit Design
- Mining Robots for Excavation, Material Handling, Setting Explosives, Mine Testing, Installing Supports, and Safety Operations
- Guided Vehicles for Coal Transport

Automated Maintenance Equipment

Cleaning Robots

- Analysis of Mining Material While Mining - Ash, Water, etc.

Coordinate Measurement (QA)

- Tool Wear Sensing
- Subsurface Material Analysis and Displays
- Subsurface and Surface Image Processing for Exploration
- Well Log Data Analysis
- Reservoir Modeling

Natural Resources

Other Handling Alternatives for Oil (Dirigibles)

- Northern Development Methods
- Geophysical:
  - 3D
  - Interpretation
  - Imaging Processors
- Environmental Models
- Payback and ROI Models
- Micros in Gas Furnaces in Houses
- Plant and Process Optimization
- Rig Crown Saver to Monitor Operation and Safety
- Automate Data Capture for Seismic Records (Scanners)

GT for RIG and Plant Manufacturing Companies

Auto Pipeline Sense and Control for Leak

- Specialty Chemicals - Sense, Analyze

New Feedback, Predicting, Analytical, etc.

- Process Control Algorithms
- Sensors:
  - H2S, Viscosity
  - Water and Chemical Analysis
- Wear on Drill Bit Sensors
- Woodlands Sensing for Fires, Roads, Erosion, Replanting, etc.

TABLE E-1. (CONTINUED)

Manufacturing

MP&CS

- ● Data Base Independent Software
- Machine Independent Software
- ● Modular Software

CAD

- ● Linkage Software from Design Geometric Model to FEM
- Kinematics Software
- Automated NC Program Generation
- Sculptured Surface Programming Languages
- ● Standard Data Formats and Representation Techniques
- Robot Programming from CAD Data Base
- ● Automatic Recognition and Digitizing of Existing Drawings
- Software for Initial Design of ICs, PCBs
- Videodisk as a Storage Medium for Computer Graphics
- Liquid Crystal, Thin-Film Displays
- Special-Purpose Processors for Parallel Processing
- Standard, Device-Independent Graphics Image Generation and Manipulation Languages
- High-Level Programming Languages Tied to Specific Applications, i.e., Mining, Agriculture

CAM

- Robot Vision (Especially Low-Cost)
- ● Robot Tactile
- Cleaner Method for Handling Wafers on VLSI Production Lines
- ● Off-Line Robot Programming
- ● Semiautomated Robot Programming
- Programming Languages for Manufacturing Cells
- Engineering and Manufacturing Data Base Integration
- Adaptive Control
- Machine Tool Diagnostics
- ● Modular Software for CAM Applications
- ● Sensors for Automated Welding
- ● Manufacturing Process Models Developed for Industry

AMH

- Unmanned Trucks
- ● Mobile Robotics
- Improved Simulation Software Packages for AMH System Design
- Improved Warehause Management Software

GT

- Automated or Semiautomated GT Coding Software
- ● GT System Suited for Both:
  - Design-Retrieval
  - Grouping of Part Families for Production
- ● Generative CAPP for a Specific Manufacturing Process

TABLE E-1. (CONTINUED)

Service and Utility Industry

● Medical R&D - Signal Processing

● Medical R&D - Medical Diagnostics

● Interactive Patient Care Systems

Design Analysis of Audio Effects of Materials and Room Shapes

DNA Regeneration Graphics

● Medical Image Processing

Gene Prediction

● Remote Sensing of Heart Attack Victims and Sickness

● Computer Modeling in Medicine - Body Movements

Vitamin Analysis and Production

● Pollution Monitor and Control

Weather Control

Satellite System Development and Applications and R&D

● Digital Transmission Research

● Remote Graphics on Trucks for Drawing and Maps

User Friendly Portable CAD Systems

Intelligent Forklift for High Rises

TABLE E-2. APPLICATION/UTILIZATION OPPORTUNITIES FOR CAD/CAM IN ALBERTA

Agriculture

● Egg System:
  - Sense and Control

● Egg System:
  - Inspect and Package

● Meat Packaging and Labeling

● Farm Management Software:
  - Financial Records
  - Livestock Records
  - Agribusiness
  - Marketing Analysis
  - Forecasting

● Breeding History of Cattle

● Genetics, Correlation of Breeding Data

● Feed Analysis

● Grain Transportation System Management

● Provincial and Federal Crop Management Software

● 50 Farming Data Bases Exist in Alberta - Get to Farmers

● Remote Telemetry to Home

● Farm Networks

● Information System to Farmer

● Education Systems

● Time Share Systems to a Large Host

● Water Flow Measure and Control

● Remote Sensing:
● - Disease
● - Locusts
● - Crop Production
  - Demographics
● - Future Expansion
● - Crop Maturity

● Weather Prediction

Architecture, Engineering, and Construction

● Building Codes and Standards on CAD System

● Project Management

● Resource Management (Labor, Materials, Subcontractors, and Equipment)

● Graphic CP and PERT

● Financial Control

● Financial and Economic Modeling

● Automate Bill of Materials for Building

● Management Software for Architecture Methods and Procedures

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● - Opportunities which passed Go/No-Go screening.

TABLE E-2. (CONTINUED)

Architecture, Engineering, and Construction (Continued)

- Project Management Packages
- Modularity of Building Parts and Concepts

Building Maintenance and Management on CAD

Building Service and Maintenance Data Bases for Each Building With Graphics

- Building Management, Scheduling and Energy Conservation on Line for the Building
- Network Status of Construction to Control Computer for Up-to-Date Project Status

Paperless Operations With Remote Graphics on Site

- Visual Progress Tracking on CRT; Actual and Expected Work Completed (Building, Highways, Pipelines)
- Software for Sketches, Concept Drawings, and Marketing Materials
- Steel Detailing Designs in Data Base

Small Tools Handling by Robot

- Plant Control for Materials Building System

Forestry

Forestry Reserves Data Base Defining Species, Size, Density, Accessibility, Quotas

- Graphic Display of Above Resource Data

Merging of all Demographic, Resource, Topographic, Social Economic, Political Data Bases With Graphics

- Layout Graphics of Roads, Lumber Type, Timbering Patterns for Hauling Optimization and Economic Analysis
- Resource Management With Financial and Market Management
- Project Management of Sawmills and Factories (Schedules, Costs, etc.)
- Logging Site Tree Chippers
- Optimizing Cutting of Logs
- Sawmill Material Handlers
- CAD for Precasting Forms and Wood Construction Materials
- Automated Handling and Packaging of Finished Wood

CNC Woodworking Machines

TABLE E-2. (CONTINUED)

High Technology

- Telecommunications
- Data Communications

Cellular Mobile Radio Communications

- Test Equipment - Telecom
- Electronic Home Security Systems
- CAI for Medical Research
- Subsidize Personal Computers and Software to Companies
- Laser Cutting and Marking

Long Baseline Arrays for a Large Radio Telescope Across Canada

New Credit Card and Payment System

Videotext, ISDN

Natural Resources

- Geophysical:
  - Image Processing
  - Graphics
- Mapping:
  - Data Bases
  - Natural Resources
  - Topographics
- Seismic Data Base
- Remote Data Collection
- Natural Resources Network for SCADA
- SCADA especially for up North
- Exploration Mapping

Aerial Photography

- Satellite Sensing for Forest Fires and Disease
- Seismic Data Collection

Gamma Spectrometry

- Wire Line Logging
- Real-Time Analysis Display of Drill Bit Wear
- Dynamic Analysis and Modeling

Remote Meter Reading

- Drilling Simulators

TABLE E-2. (CONTINUED)

Service and Utility Industry

Glass Products and Cutting

- Optimized Cutting
- Prescription Glass Cutting Automated

Automatic Drycleaning Plant

Optimization of Service Tools - Saw Sharpening

Robotics for Public Storage Warehouses and Lockers

- Medical Lab Test
- Analysis Documentation Systems

Guidance of Blind To and From Wheelchair

Sonar Sensing

- Integrated Data Bases Between Vendors
- Environmental Pollution Monitor and Report
- Weather Prediction and Mapping
- MP&CS for:
  - Project Management (MRP)
  - Northern Supply Center
  - Municipal Resource
  - Utility Management
- CAI - Software
- CAI - Laser Discs
- CAI for Management, Entrepreneuring, Resource Management (Alberta's Strengths)

Office Retrofitting
- Power Line Carrier

- Automated Ordering to Retain and Supplier
- CAI for Doctor and Patient Training
- CAI - Handicap Education

Student Recordkeeping

- CAI - Courseware
- Curriculum Management
- Multimedia Education
- Remote Education
- Devices to Rural Areas
- Index and Classification Schemes
- Software Productivity Tools
- Subdivision Layout and Optimization
- Cross Correlation Software for Multiple Data Bases for Provincial Demographics
- Social Economic Data Bases for Committee and Province

TABLE E-2. (CONTINUED)

Service and Utility Industry (Continued)

Portable Graphics Maps on Line in Planes and Trucks

TV and Film Animations and Simulations

- Mapping:
  - Municipal
  - Cultural, Topo, Contours
- Data Base, Machine Readable
- Building Maintenance Control

Tank Metal Inspection

- Remote Meter Reading, Alarm Monitoring and Energy Load Control

Manufacturing

Laser Welding

Laser Cutting

- Laser Marking

Motors, Pumps, Valves

- Explosion Proof Safety Valves and Products
- CAD/CAM for Albertan Industry Metal Products
- Handling Equipment
- Intelligent Conveyors and Handling Systems

Gear Manufacturing

- Semiautomated Welding Jigs
- Plastic/Glass/Cans
- Plastic Molds - CAD/CAM
- Develop Small Automated Food Processing Factories for Alberta (Fish Filleting, Freezing, Packaging, Vegetables, Meats, Etc.)
- Flour Milling

Baking and Cake Making

Automated Restaurants

Largest Import Food Products

- Largest Usage Food

Beef Substitutes

- Dehydrated and Freeze Dried Foods
- Food Mixers
- Standard Packages and Products (Pellets)

Continuous Noodle Making

- Food and Beverage Handling Systems

Pigs (Inside Pipeline Robots)

- Plastic Products
- Automated Metal Fab

Pipelines for Solids

TABLE E-2. (CONTINUED)

Manufacturing (Continued)

Metal Recovery
  - Scrap Metals (Separation of Materials)
  - Plastics
  - Glass
  - Newsprint

- Export of the Products Which Which Have Most Value Added From Alberta Raw Material
  - Vegetables
  - Water
  - Petrochemical
  - Shoes
  - Food Oils
  - Lumber Products
  - Newsprint
  - Furniture

Conveyor Systems

Automated Warehouse

Bar Codes Inventory

Automated Greenhouse

- Automated Metal Fab Factory
- Small Automated Plastic Manufacturing Systems
- Small Automated Foundries, Mold Makers, Material Handlers
- Automated Sash, Cabinet, Doors, Fabrication and Milling Plants
- CAD/CAM for Industry Metal Products
- CAD - Low Cost Turnkey (Metal Fab)

Mold Design

Gear Design

Beam Line Technology for Steel Beams

Mining

- Mapping Data Base
- Mapping for Exploration
- Plot Product Quality and Quantity on Maps
- Resource Management for Exploration, Excavation, Borrow Pits, Mining, Transport Process and Market
- Project Management of Operations
- Energy Management Systems
- Gas Sensors - Methane, Dust, Fire, CO_2, Sulphur
- Coal Process Units Computer Controlled
- Coal Field Analysis Software
- Coal Quality Analysis Software
- Economic Feasibility Software
- Computer Processing of Seismic and Electromagnetic Exploration Data
- CAD for Mining Facilities
- CAD for Reclamation

TABLE E-3. OPPORTUNITIES FOR CAD/CAM PRODUCTS AND SERVICES FOR ALBERTA

Agriculture

CAD for Large Farm Layout

Up North Greenhouse

Soya Production

● Manufacture By-Products:
- Cereals
- Prepared Meats
- Oils
- Dairy Produce
- Beverages
- Hides (Tanning)
- Shoes
- Wool and Clothes
- Leather Products
- Furs

Manufacture Farm Equipment:
- Implements
- Tractors
- Farm Electronics

● Weight Monitors in Trucks and Hoppers (Board Cells)

● Container Systems for Grain

● Energy Management in Buildings

● Monitor Heat Lamps for Pig Farms

Power Load Shedding (Energy)

● Seeding Monitors

● Spray Monitors

● Moisture Sensors:
- Grain
- Field
- Ground
- For Irrigation

● Security Systems

Fencing (Invisible)

● Pelletizing of Products

Container and Label Machines

● Aseptic Packaging

Concentrated Foods

Chemical Additives

Architecture, Engineering and Construction

Low Cost CAD Workstation (S/W Product)

Building and Landscape Graphics for Concept Design

Building Energy Management Design Software

Plant Design Package

Turnkey Design Packages

Net List Generation (Material Lists)

Automatic Glass Cutting and Handling

Prefab House Design, Cutting and Assembly Software

Solar Energy Products

● Energy Management Systems

● Security Systems

Cement Plant Process Control Systems

● - Opportunities which passed Go/No-Go screening.

TABLE E-3. (CONTINUED)

Forestry

Manufacture By-Products:
- LUmber
- Furniture
- Plywood
- Newsprint
- Cardboard
- Pulp
- Books
- Newspapers
- Office Supplies

High Technology

- Manufacture Conveyor Systems
- Coal and Heavy Oil Handlers to be Exported
- Pneumatic Pipelines for Solids
- Civil Engineering Data Base
- Mapping Software

Total Business Management Software

Military Products

- Education Software
- Medical Electronics
- Health Care Electronics
- Energy Conservation Systems
- Intensive Care Systems

Amusement Services

Manufacturing

DNC Interface Links

Post Processor Development for NC Machines

- Voice Activated Systems for Dangerous Jobs

QA Coordinate Measurement Systems

- Automatic Pelleting Systems
- Configuration Control Software
- Plain-Language Graphics Programs
- Plug-In Fimr Ware Semiconductor Modules for Graphics
- Applications Software to Format Gusiness Graphics; Interactive With Business-Type Language

Low-Cost CNC Controls

Low-Cost Robots for Loading and Unloading

TABLE E-3. (CONTINUED)

Mining

Field Analysis Software

Conveyor Systems

Mining Communication Networks

Mining Development Graphics Showing Layouts of Tunnels

Manufacture Secondary Products:
  - Coke
  - Chemicals
  - Pitch
  - Drugs
  - Plastics
  - Solvents

Natural Resources

- Resource Management:
  - Inventory
  - Analysis
  - Data Capture
  - Forecasting
  - Market Forecast
  - Sell to Third World

- Resource Management of:
  - Oils
  - Gas
  - Heavy Oils
  - Water

- Plant Simulation and Modeling

- Slurry Pipeline Solids and Liquid Export

- Portable Pipeline Units for Machining and Cutting

- Well Blowout Detection

- Underground Pressure Sensing

Up North Vehicles

Service and Utility Industry

- Smart Hospital Beds and Patient Carriers

Self-Feed Systems for Handicapped

- Garbage Manipulator Units for Garbage Collectors

- Janitorial Robots

Domestic Robots

Robot to Lift Handicaps to and From Wheelchair

Robot Guidance of Blind in Hospitals

Optic Discs

- CCD Scanners, Character Recognition and Drawing Scanners for Data Capture

- Underground Conveyors

APPENDIX F

EXAMPLES OF DATA BASES

TABLE F-1. EXAMPLES OF DATA BASES

File No.	**DATABASE (supplier)** **By Database Number**	Online Connect Time Rate $/Hour	Offline Print Rate Per Full Record	Online Type or Display Rate Per Full Record	Classroom Instruction Program
1	ERIC (Educational Resources Information Center)	$25	10¢		-
5	BIOSIS PREVIEWS 1977–present (BioSciences Information Service)	65	15		-
6	NTIS (National Technical Info. Service, U.S. Dept. of Commerce)	45	15		-
7	SOCIAL SCISEARCH® (Institute for Scientific Information) nonsubscribers	110	20		-
7	SOCIAL SCISEARCH® (Institute for Scientific Information) subscribers	75	15		-
8	COMPENDEX (Engineering Information, Inc.)	98	40	30¢	-
9	AIM ARM (Center for Vocational Education)	25	10		-
10	AGRICOLA (U.S.D.A. Technical Information Systems)	35	10		-
11	PSYCINFO (American Psychological Assoc.)	65	10		-
12	INSPEC 1969–1976 (Institution of Electrical Engineers)	85	35	25	-
13	INSPEC 1977–present (Institution of Electrical Engineers)	85	35	25	-
14	ISMEC (Cambridge Scientific Abstracts)	73	20	15	-
15	ABI INFORM (Data Courier, Inc.)	73	30	20	-
17	PTS ANNUAL REPORTS ABSTRACTS (Predicasts, Inc.)	To be announced			-
16	PTS PROMT (Predicasts, Inc.)	95	40	35	-
18	PTS F&S INDEXES 1979–present (Predicasts, Inc.)	95	25	20	-
19	CHEMICAL INDUSTRY NOTES (American Chemical Society)	74	25	12	
20	FEDERAL INDEX (Capitol Services International)	90	20		-
21	NCJRS (National Criminal Justice Reference Service)	35	15	10	-
22	EIS INDUSTRIAL PLANTS (Economic Information Systems, Inc.)	90	50	50	-
23	CLAIMS™ U.S. PATENT ABSTRACTS 1950–1970 (IFI Plenum Data Company)	95	50	25	
24	CLAIMS™ U.S. PATENT ABSTRACTS 1971–1981 (IFI Plenum Data Company)	95	50	25	
25	CLAIMS™ U.S. PATENT ABSTRACTS 1982–present (IFI Plenum Data Company)	95	50	25	
26	FOUNDATION DIRECTORY (The Foundation Center)	60	30		-
27	FOUNDATION GRANTS (The Foundation Center)	60	30		-
28	OCEANIC ABSTRACTS (Cambridge Scientific Abstracts)	73	30	25	-
29	METEOROLOGICAL & GEOASTROPHYSICAL ABSTRACTS (American Meteorological Society & NOAA)	95	15		
30	CHEMSEARCH (Chemical Abstracts Service & DIALOG Information Services, Inc.)	138	25	12	
32	METADEX (American Society for Metals)	80	15	10	-
33	WORLD ALUMINUM ABSTRACTS (American Society for Metals)	50	10		-
34	SCISEARCH® 1981–present (Institute for Scientific Information) Subscribers	65	15		-
34	SCISEARCH® 1981–present (Institute for Scientific Information) Nonsubscribers	165	25		-
35	COMPREHENSIVE DISSERTATION INDEX (Univ. Microfilms Int'l.)	70	20		-
36	LANGUAGE & LANGUAGE BEHAVIOR ABS. (Sociological Abs., Inc.)	55	15		-
37	SOCIOLOGICAL ABSTRACTS (Sociological Abstracts, Inc.)	55	15		-
38	AMERICA: HISTORY & LIFE (ABC-Clio, Inc.)	65	15		-
39	HISTORICAL ABSTRACTS (ABC-Clio, Inc.)	65	15		-
40	ENVIROLINE® (Environment Information Center, Inc.)	90	25	15	-
41	POLLUTION ABSTRACTS (Cambridge Scientific Abstracts)	73	20	15	-
42	PHARMACEUTICAL NEWS INDEX (Data Courier, Inc.)	95	30	25	-
43	ADTRACK (Corporate Intelligence, Inc.)	95	25	25	-

Source: DIALOG Information Services Inc., January 1983.

TABLE F-1. Continued

File No	**DATABASE (supplier)** **By Database Number**	Online Connect Time Rate $/Hour	Offline Print Rate Per Full Record	Online Type or Display Rate Per Full Record	Classroom Instruction Program
44	AQUATIC SCIENCE & FISHERIES ABSTRACTS (NOAA, Cambridge Scientific Abstracts)	$ 75	30¢	20¢	
45	APTIC (Air Pollution Tech. Info. Ctr. and The Franklin Institute)	35	10		-
46	NICEM (National Information Center for Educational Media)	70	20		
47	MAGAZINE INDEX (Information Access Corp.)	75	20		-
49	PAIS INTERNATIONAL (Public Affairs Information Service, Inc.)	60	15		-
50	CAB ABSTRACTS (Commonwealth Agricultural Bureaux)	55	35	25	-
51	FOOD SCIENCE AND TECHNOLOGY ABSTRACTS (International Food Information Service)	65	15		-
52	TSCA INITIAL INVENTORY (Environmental Protection Agency & DIALOG Information Services, Inc.)	45	15		-
53	IRIS (U.S. Environmental Protection Agency Information Project)	35	10		-
54	EXCEPTIONAL CHILD ED. RESOURCES (Council for Except. Children)	25	10		-
55	BIOSIS PREVIEWS 1969–1976 (BioSciences Information Service)	65	15		-
56	ARTBIBLIOGRAPHIES MODERN (ABC-Clio, Inc.)	60	15		-
57	PHILOSOPHER'S INDEX (Philosophy Documentation Center)	55	15		-
58	GEOARCHIVE (Geosystems)	70	20		-
60	CRIS USDA (USDA)	35	10		-
61	LISA (Learned Information Ltd.)	75	25		
62	SPIN (American Institute of Physics)	35	10		-
63	TRIS (U.S. Department of Transportation and Transportation Research Board)	40	10		
64	CHILD ABUSE & NEGLECT (National Center for Child Abuse and Neglect)	35	10		-
65	SSIE CURRENT RESEARCH (National Technical Information Service U.S. Department of Commerce)	78	20		-
66	GPO MONTHLY CATALOG (U.S. Government Printing Office)	35	10		-
67	WORLD TEXTILES (Shirley Institute)	55	10		-
68	ENVIRONMENTAL BIBLIOGRAPHY (Environmental Studies Institute)	60	15		-
69	ENERGYLINE® (Environment Information Center, Inc.)	90	25	15	-
70	NICSEM NIMIS (National Info. Cntr. for Special Education Materials)	35	10		
71	MLA BIBLIOGRAPHY (Modern Language Association)	55	15		-
72	EXCERPTA MEDICA 1980–present (Excerpta Medica)	75	25	8	-
73	EXCERPTA MEDICA IN PROCESS (Excerpta Medica)	75	25	8	-
74	INTERNATIONAL PHARMACEUTICAL ABS. (Am. Soc. of Hospital Pharmacists)	55	20		-
75	MANAGEMENT CONTENTS® (Management Contents, Inc.)	80	35	20	-
76	LIFE SCIENCES COLLECTION (Cambridge Scientific Abstracts)	45	15		-
77	CONFERENCE PAPERS INDEX (Cambridge Scientific Abstracts)	73	20	15	-
78	NATIONAL FOUNDATIONS (The Foundation Center)	60	30		
79	FOODS ADLIBRA (Komp Information Services)	55	10		-
81	PTS U.S. FORECASTS (Predicasts, Inc.)	95	25	20	-
82	PTS U.S. TIME SERIES (Predicasts, Inc.)	95	40	35	-
83	PTS INTERNATIONAL FORECASTS (Predicasts, Inc.)	95	25	20	-
84	PTS INTERNATIONAL TIME SERIES (Predicasts, Inc.)	95	40	35	-

TABLE F-1. Continued

File No.	**DATABASE (supplier)** **By Database Number**	Online Connect Time Rate $/Hour	Offline Print Rate Per Full Record	Online Type or Display Rate Per Full Record	Classroom Instruction Program
85	GRANTS (Oryx Press)	$60	30¢		-
86	* MENTAL HEALTH ABSTRACTS (National Clearinghouse for Mental Health Information National Institute of Mental Health)	30	10		-
88	BIOGRAPHY MASTER INDEX (Gale Research Company)	55	15		-
89	GEOREF (American Geological Institute)	82	20	10¢	
90	ECONOMICS ABSTRACTS INTERNATIONAL (Dutch Ministry of Economic Affairs)	65	20		
91	POPULATION BIBLIOGRAPHY (University of North Carolina Carolina Population Center)	55	10		-
92	EIS NONMANUFACTURING ESTABLISHMENTS (Economic Information Systems Inc)	90	50	50	-
93	U S POLITICAL SCIENCE DOCUMENTS (Univ of Pittsburgh Cntr for International Studies)	65	15		-
94	SCISEARCH* 1978–1980 (Institute for Scientific Information) Subscribers	65	15		-
94	SCISEARCH* 1978–1980 (Institute for Scientific Information) Nonsubscribers	165	25		-
96	BHRA FLUID ENGINEERING (British Hydromechanics Research Assn)	65	15		-
97	RILM ABSTRACTS (City University of New York International RILM Center)	65	15		-
98	PTS F&S INDEXES 1972–1978 (Predicasts Inc)	95	25	20	-
99	WELDASEARCH (The Welding Institute)	75	20		-
100	DISCLOSURE II (Disclosure Incorporated)	60	$10	$6	-
101	CIS (Congressional Information Service Inc)	90	25¢		-
102	ASI (Congressional Information Service Inc)	90	25		-
103	DOE ENERGY (U S Dept of Energy)	40	15		
105	FOREIGN TRADERS INDEX (U S Department of Commerce)	45	25		
106	TRADE OPPORTUNITIES (U S Department of Commerce)	45	25		
107	TRADE OPPORTUNITIES WEEKLY (U S Department of Commerce)	45	50	50¢	
110	AGRICOLA 1970–1978 (U S D A Technical Information Systems)	35	10		-
111	NATIONAL NEWSPAPER INDEX (Information Access Corporation)	75	20		-
112	AQUACULTURE (National Oceanic and Atmospheric Administration)	35	15	10	
113	STANDARDS AND SPECIFICATIONS (National Standards Association Inc)	65	30	20	-
114	ENCYCLOPEDIA OF ASSOCIATIONS (Gale Research Company)	45	25	20	-
115	SURFACE COATINGS ABSTRACTS (Paint Research Association of Great Britain)	65	15		-
116	AQUALINE (Water Research Centre)	35	30	25	-
117	WATER RESOURCES ABSTRACTS (U S Dept of the Interior)	45	15		-
118	NONFERROUS METALS ABSTRACTS (British Non-Ferrous Metals Technology Centre)	45	20	10	-
119	TEXTILE TECHNOLOGY DIGEST (Institute of Textile Technology)	65	15		-
120	U S PUBLIC SCHOOL DIRECTORY (National Center for Educational Statistics)	35	10		-
122	HARVARD BUSINESS REVIEW (John Wiley & Sons Inc)	To be announced			
123	INPADOC (International Patent Documentation Center)	95	20		
124	CLAIMS™ CLASS (IFI Plenum Data Company)	95	10		-

*Forthcoming database

TABLE F-1. Continued

File No	DATABASE (supplier) By Database Number	Online Connect Time Rate $/Hour	Offline Print Rate Per Full Record	Online Type or Display Rate Per Full Record	Classroom Instruction Program
125	CLAIMS™ U S PATENT ABSTRACTS WEEKLY (IFI Plenum Company)	$95	50¢	25¢	
126	U S EXPORTS (U S Department of Commerce)	45	25	25	
128	BI DATA TIME SERIES (Business International Corp)	85	$1 50	$1 50	-
129	BI DATA FORECASTS (Business International Corp)	85	55 00	55 00	-
132	STANDARD & POOR S NEWS (Standard & Poor s Corp)	85	15¢		
133	STANDARD & POOR S NEWS DAILY (Standard & Poor s Corp)	85	15		
135	★ CONGRESSIONAL RECORD ABSTRACTS (Capitol Services Int l)	75	15		-
136	FEDERAL REGISTER ABSTRACTS (Capitol Services Int l)	75	20		-
137	BOOK REVIEW INDEX (Gale Research Company)	55	15		-
139	JOURNAL OF ECONOMIC LITERATURE (American Economic Association)	75	15		-
148	TRADE AND INDUSTRY INDEX (Information Access Corp)	85	20		-
150	LEGAL RESOURCE INDEX (Information Access Corp)	90	20		-
151	HEALTH PLANNING AND ADMINISTRATION (U S National Library of Medicine)	35	15		
152	MEDLINE 1966–1972 (U S National Library of Medicine)	35	15		-
153	MEDLINE 1973–1979 (U S National Library of Medicine)	35	15		-
154	MEDLINE 1980–present (U S National Library of Medicine)	35	15		-
162	CAREER PLACEMENT REGISTRY EXPERIENCED PERSONNEL (Career Placement Registry, Inc)	50	$1 50	1 00	-
163	CAREER PLACEMENT REGISTRY STUDENT (Career Placement Registry Inc)	50	1 50	1 00	-
164	COFFEELINE (International Coffee Organization)	55	15¢		-
165	EI ENGINEERING MEETINGS (Engineering Information, Inc)	98	40	30¢	-
166	GPO PUBLICATIONS REFERENCE FILE (U S Government Printing Office)	35	10		-
167	★ WORLD AFFAIRS REPORT (California Institute of International Affairs)	90	25	10¢	-
168	INSURANCE ABSTRACTS (University Microfilms International)	55	15		-
169	ENERGYNET (Environment Information Center)	90	50		-
170	ONLINE CHRONICLE (Online, Inc.)	35	30	15	-
171	CRIMINAL JUSTICE PERIODICAL INDEX (University Microfilms International)	55	15		-
172	EXCERPTA MEDICA 1974–1979 (Excerpta Medica)	75	25	8	
174	CHEMICAL REGULATIONS AND GUIDELINES SYSTEM (U.S. Interagency Regulatory Group, CRC Systems, Inc)	70	90		-
175	BLS CONSUMER PRICE INDEX (Bureau of Labor Statistics, U S Dept of Labor)	45	50	50	-
176	BLS PRODUCER PRICE INDEX (Bureau of Labor Statistics, U S Dept of Labor)	45	50	50	-
177	BLS LABOR FORCE (Bureau of Labor Statistics, U S Dept of Labor)	45	50	50	-
178	BLS EMPLOYMENT, HOURS, AND EARNINGS (Bureau of Labor Statistics, U S Dept of Labor)	45	50	50	-
185	ZOOLOGICAL RECORD (BioSciences Information Service and the Zoological Society of London)	78	20		-
186	SCISEARCH® 1974–1977 (Institute for Scientific Information) Subscribers	65	15		-
186	SCISEARCH® 1974–1977 (Institute for Scientific Information) Nonsubscribers	165	25		-

★Forthcoming database

TABLE F-1. Continued

File No.	DATABASE (supplier) By Database Number	Online Connect Time Rate $/Hour	Offline Print Rate Per Full Record	Online Type or Display Rate Per Full Record	Classroom Instruction Program
187	★ SCISEARCH® 1970–1973 (Institute for Scientific Information) Subscribers	$65	15¢		-
187	★ SCISEARCH® 1970–1973 (Institute for Scientific Information) Nonsubscribers	165	25		-
189	HARFAX INDUSTRY DATA SOURCES (Harper & Row Publishers, Inc.)	75	30		-
194	COMMERCE BUSINESS DAILY (U.S. Department of Commerce) backfile	54	35	25¢	
195	COMMERCE BUSINESS DAILY (U.S. Department of Commerce)	54	35	25	
196	FIND SVP REPORTS AND STUDIES INDEX (FIND SVP)	65	25		-
197	CHEMLAW (Bureau of National Affairs, Inc. Fein-Marquart Associates, Inc.)	150	1 50		-
198	★ CATFAX DIRECTORY OF MAIL ORDER CATALOGS (Grey House Publishing, Inc.)	65	15		-
200	DIALOG PUBLICATIONS (DIALOG Information Services, Inc.)	15	15		
201	ONTAP® ERIC	15	na		
204	ONTAP® CA SEARCH	15	na		
208	ONTAP® COMPENDEX	15	na		
211	NEWSEARCH (Information Access Corp.)	95	20		
213	ONTAP® INSPEC	15	na		
215	ONTAP® ABI INFORM	15	na		
216	ONTAP® PTS PROMT	15	na		-
220	CLAIMS™ CITATION–prior to 1947 (IFI Plenum Data Company)	95	$50 00	$50 00	
221	CLAIMS™ CITATION 1947–1970 (IFI Plenum Data Company)	95	50 00	50 00	
222	CLAIMS™ CITATION 1971–present (IFI Plenum Data Company)	95	20 00	20 00	
223	CLAIMS™ UNITERM '50–'70 (IFI Plenum Data Company)	300	15¢		
224	CLAIMS™ UNITERM '71–'81 (IFI Plenum Data Company)	300	15		
225	CLAIMS™ UNITERM '82–present (IFI Plenum Data Company)	300	15		
231	ONTAP® CHEMNAME	15	na		
232	INTERNATIONAL SOFTWARE DATABASE (Imprint Software Ltd.)	60	15		-
233	MICROCOMPUTER INDEX (Microcomputer Information Services)	45	15		-
234	★ MARQUIS WHO'S WHO (Marquis Who's Who, Inc.)	To be announced			
236	★ AMERICAN MEN AND WOMEN OF SCIENCE (R. R. Bowker)	95	40		-
238	TELEGEN (Environment Information Center, Inc.)	90	25	15¢	-
239	MATHFILE (American Mathematical Society)	55	20		-
240	PAPERCHEM (Institute of Paper Chemistry)	65	25	15	-
241	ELECTRIC POWER DATABASE (Electric Power and Research Institute)	55	15		-
242	CLAIMS COMPOUND REGISTRY (IFI Plenum Data Co.)	95	15		
243	PATLAW (Bureau of National Affairs, Inc.)	120	70		-
244	LABORLAW (Bureau of National Affairs, Inc.)	120	70		-
245	WATERNET (American Water Works Association)	80	20	10	-
254	ONTAP® MEDLINE	15	na		
290	ONTAP® DIALINDEX (DIALOG Information Services, Inc.)	15	na		-
300	CHEMZERO (Chemical Abstracts Service & DIALOG Information Services, Inc.)	138	25	12	
301	CHEMNAME™ (Chemical Abstracts Service & DIALOG Information Services, Inc.)	138	25	12	

★Forthcoming database

TABLE F-1. Continued

File No.	**DATABASE (supplier)** **By Database Number**	Online Connect Time Rate $/Hour	Offline Print Rate Per Full Record	Online Type or Display Rate Per Full Record	Classroom Instruction Program
308	CA SEARCH 1967–1971 (American Chemical Society)	$68	25c	12c	
309	CA SEARCH 1972–1976 (American Chemical Society)	68	25	12	
310	CA SEARCH 1980–1981 (American Chemical Society)	68	25	12	
311	CA SEARCH 1982–present (American Chemical Society)	68	25	12	
320	CA SEARCH 1977–1979 (American Chemical Society)	68	25	12	
328	CHEMSIS™ 1967–1971 (Chemical Abstracts Service & Dialog Information Services, Inc.)	138	25	12	
329	CHEMSIS™ 1972–1976 (Chemical Abstracts Service & DIALOG Information Services, Inc.)	138	25	12	
330	CHEMSIS™ 1977–1981 (Chemical Abstracts Service & DIALOG Information Services, Inc.)	138	25	12	
331	CHEMSIS™ 1982–present (Chemical Abstracts Service and DIALOG Information Services, Inc.)	138	25	12	
410	CHRONOLOG NEWSLETTER (DIALOG Information Services, Inc.)	15	15		•
411	DIALINDEX™ (DIALOG Information Services, Inc.)	35	na	na	
421	REMARC Pre-1900 and undated (Carrollton Press)	85	35	25	•
422	REMARC 1900–1939 (Carrollton Press)	85	35	25	•
423	REMARC 1940–1959 (Carrollton Press)	85	35	25	•
424	REMARC 1960–1969 (Carrollton Press)	85	35	25	•
425	REMARC 1970–1980 (Carrollton Press)	85	35	25	•
426	★ LC MARC (U.S. Library of Congress)	45	15	10	•
470	BOOKS IN PRINT (R. R. Bowker)	65	20		•
480	★ ULRICH'S INTERNATIONAL PERIODICAL DIRECTORY (R. R. Bowker)	65	20		•
501	ELECTRONIC YELLOW PAGES–FINANCIAL SERVICES DIRECTORY (Market Data Retrieval, Inc.)	60	20	20	•
502	ELECTRONIC YELLOW PAGES–PROFESSIONALS DIRECTORY (Market Data Retrieval, Inc.)	60	20	20	•
503	ELECTRONIC YELLOW PAGES–WHOLESALERS DIRECTORY (Market Data Retrieval, Inc.)	60	20	20	•
504	ELECTRONIC YELLOW PAGES–RETAILERS DIRECTORY, SIC Codes 5200–5499 (Market Data Retrieval, Inc.)	60	20	20	•
505	ELECTRONIC YELLOW PAGES–RETAILERS DIRECTORY, SIC Codes 5500–5799 (Market Data Retrieval, Inc.)	60	20	20	•
506	ELECTRONIC YELLOW PAGES–RETAILERS DIRECTORY, SIC Codes 5800–5999 (Market Data Retrieval, Inc.)	60	20	20	•
507	ELECTRONIC YELLOW PAGES–CONSTRUCTION DIRECTORY (Market Data Retrieval, Inc.)	60	20	20	•
508	ELECTRONIC YELLOW PAGES–SERVICES DIRECTORY, SIC Codes 7000–7299 (Market Data Retrieval, Inc.)	60	20	20	•
509	ELECTRONIC YELLOW PAGES–SERVICES DIRECTORY, SIC Codes 7300–7999 (Market Data Retrieval, Inc.)	60	20	20	•
510	ELECTRONIC YELLOW PAGES–MANUFACTURERS DIRECTORY (Market Data Retrieval, Inc.)	60	20	20	•
516	DUN'S MARKET IDENTIFIERS® 10+ (Dun's Marketing Services)	100	$1.50	$1.50	•
517	MILLION DOLLAR DIRECTORY® (Dun's Marketing Services)	100	1.50	1.50	•

★Forthcoming database

TABLE F-2. AVAILABLE PACKAGES FOR PLANNING AND PROJECT MANAGEMENT

1. AGS Management Systems, Inc.
320 Walnut Street
Philadelphia PA 19106

PAC I

CPM/PERT
Network scheduling and budgeting

PAC III

Same as PAC I but more sophisticated

2. Systonetics, Inc.
801 East Chapman Avenue
Fullerton CA 92631

VISION

3. SIS Corporation
Project Management Service
Glenhardie Corporate Center
1285 Drummers Lane
Wayne PA 19087

SUNPLAN II

4. Trimag
Suite 1300, Royal Trust Tower
Edmonton Centre
Edmonton, Alberta T5J 2Z2

COSTIME
Micro based

5. POSI
14 Story Street
Cambridge MA 02138

PROJECT/2
VAX 11/370

POOR

QUALITY

ORIGINAL